The Rural Manuals

EDITED BY L. H. BAILEY

SPRAYING, DUSTING AND FUMIGATING OF PLANTS

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MANUAL OF GARDENING—*Bailey*

MANUAL OF FARM ANIMALS—*Harper*

FARM AND GARDEN RULE-BOOK—*Bailey*

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SPRAYING, DUSTING AND FUMIGATING OF PLANTS—*Mason*

SPRAYING, DUSTING AND FUMIGATING OF PLANTS

A Popular Handbook on Crop Protection

BY

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THIS BOOK IS AFFECTIONATELY DEDICATED

TO MY MOTHER AND FATHER

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THE preparation of a manual of this nature would have been impossible without help from many sources, since first-hand knowledge of all the fields covered is patently out of the question. Consequently the author has borrowed freely from all books and bulletins available. *Spraying of Plants* by E. G. Lodeman, *Manual of Fruit Insects* by Slingerland and Crosby, *Manual of Fruit Diseases* by Hesler and Whetzel, *Manual of Vegetable-Garden Insects* by Crosby and Leonard, *Manual of Vegetable-Garden Diseases* by Chas. Chupp, *Insecticides, Fungicides and Appliances* by Anderson and Roth, *Insecticides, Fungicides and Weed-killers* by E. Bourcart, *Citrus Diseases and Their Control* by Fawcett and Lee, *Diseases of Truck Crops* by J. J. Taubenhaus, and United States Department of Agriculture and State Experiment Station bulletins were extensively used in preparing this manuscript. Some of these have been cited in the text, when material was borrowed outright. Others, used indirectly, are not specifically mentioned.

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PREFACE

Rapid progress has been made, especially during recent years, in the methods of combating the enemies of orchard, garden and farm. The increasing number of pests which confront the farmer, the necessity of reducing production costs by growing larger crops to the acre, the more fastidious taste of the consumer, and other influences have led to the invention of new machinery and to the discovery or manufacture of new spray materials for dealing with these troubles. The changes have been frequent and sometimes radical. In 1880 only the crudest forms of spraying were practiced, while very little was known about the habits of the insects and diseases then recognized. Since then the entomologist and plant pathologist have written up in intimate detail the life histories of almost all the pests of economic importance to the grower.

Thus in the past forty years a new art has been developed. Few attempts have been made to chronicle its progress except for fragmentary accounts about certain special phases. E. G. Lodeman, in his book, *Spraying of Plants*, published in 1896, treated earlier efforts exhaustively. Since then, however, entirely new practices have been established. The rapid spread of San José scale, perhaps more than any other one thing, challenged alike the ability of the investigator, the spray-machinery manufacturer, and the grower to find a material, devise a spraying outfit, and do thorough enough spraying that together would control the pest and save the trees from actual destruction. This resulted in the improvement and standardization of lime-sulfur and the invention of reliable

power machinery for spraying. The Colorado potato-beetle, codlin-moth, and other insects had already stimulated the development of new stomach poisons. The progress made by agricultural experiment stations and manufacturers in working out new means and methods of fighting insects and diseases has brought forth a new literature.

The author has prepared this book to supply in a condensed form for the use of the commercial, professional, and amateur fruit-grower and gardener the latest information on the methods, machinery, and principles involved in combating agricultural pests. Local conditions may alter somewhat many of the recommendations, *while frequent revision will be necessary to include new information that is constantly being obtained.*

A. Freeman Mason.

February 1, 1928.

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The author wishes to express his sincere appreciation to the many organizations and individuals who loaned pictures for use in this book. The source of each borrowed picture is indicated after its title in the following list. U. S. D. A. means United States Department of Agriculture.

SPRAYING, DUSTING AND FUMIGATING OF PLANTS

SPRAYING, DUSTING AND FUMIGATING OF PLANTS

CHAPTER I

HISTORY OF SPRAYING

GARDENERS of the earliest days had their troubles with pests. With little known of entomology or pathology, their methods of protecting crops were very crude. Naturally their efforts were directed toward mechanical methods of control, through either direct removal of the insects and the affected part, or the use of repellents, while charms and incantations were highly considered.

Pliny,[1] who lived from 23 to 77 A.D., speaks in his *De Naturalis* of mildew on grains "especially when planted in valleys where there is not a good draught of wind"; of cantharides (small sucking insects); and of the phalangium, "a diminutive insect of the spider breed"; and he advises steeping the seed in wine, or mixing bruised cypress leaves with it. He quotes Democritus (born about 470 B.C.) as recommending sprinkling plants with pure amurca of olives without salt to prevent the blight from attacking them, and to destroy worms adhering to the roots. Pliny also believed in the efficacy of burying a certain herb, the name of which he does not vouchsafe, at the corners of grain-fields, to keep off flights of sparrows and starlings. "It is a wonderful thing to relate," he says, "but in such a case not a single bird will enter it." "As for mildew," continues Pliny, "that greatest

[1] Pliny. *De Naturalis* (Bostock and Riley, Trans.), Book XVIII, Chapters 44 and 45.

curse of all corn (grain), if branches of laurel are fixed in the ground, it will pass away from the field only into the leaves of the laurel."

"Many persons, for the more effectual protection of millet, recommend that a bramble frog should be carried at night around the field before the hoeing is done, and then buried in an earthen vessel in the middle of it. If this is done, they say, neither sparrows nor worms will attack the crop." The frog, however, must be disinterred before the millet is cut, for if this is neglected the produce will be bitter, according to Pliny.

It is a great advance from the superstition of Pliny's time to the effective warfare waged against plant pests today. The transition has been a sudden one. Scientific spraying, dusting and fumigation is the product of the last fifty years. The Colorado potato-beetle and San José scale, threatening the extinction of the potato and fruit industries, probably stimulated progress more than any other factors. When the light-weight steam and gasoline engines were invented the growers were quick to seize upon these devices which not only saved labor, but gave them machinery of hitherto undreamed of power and endurance.

SULFUR SPRAYS

Sulfur seems to be the only material now in use which was known to the ancients. No other modern spray materials were employed two hundred years ago. Cato states, about 200 B.C., that one method of destroying the "vine-fretter" was "to fumigate the trees with smoke from a mixture of amurca of olives, sulfur, and bitumen for three days in succession," while in 1787 J. A. E. Goeze, advising gardeners of means of controlling plant-lice said: "first wet the trees infested with lice, then rub flowers of sulfur upon the insects and it will cause them all to burst." How much of the effect is due to pressure and how much to sulfur is not brought out.

John Robertson used sulfur and soap against peach mildew in 1821; and in 1833 Wm. Kenrick made a "self-boiled" lime-sulfur, the heat for which was supplied by the slaking lime, for use in controlling grape mildew. The 8-8-50 formula of today was worked out in 1908 by W. M. Scott of the United States Department of Agriculture.

Concentrated lime-sulfur had its antecedent in "Grison's Liquid," concocted in 1851 by Grison, head gardener of the vegetable houses of Versailles, France, but the solution as used today was first employed in Australia as a sheep-dip, called "Victoria Lime-and-Sulfur Dip." Charles Hobler of Hanford, California, and A. T. Covell of Fresno claim the honor of first using it in 1880 or 1881, to control San José scale which had been introduced into that neighborhood from China a few years before. Peach trees sprayed for scale with this material were noted to be free from peach leaf-curl, and the fungicidal value was again established. A. B. Cordley, of the Oregon Agricultural Experiment Station, discovered its possibilities as a summer spray quite by accident in 1908, using it as a substitute for bordeaux mixture to control apple-scab, getting better disease control with less burning of the fruit and foliage. Since then it has been the standard fungicide for use on pome-fruits. The dry form was put on the market by the Sherwin-Williams Company, Cleveland, Ohio, in 1915. Other dry sulfur compounds have also been introduced, such as soluble sulfur and barium tetrasulfid.

Wettable sulfurs, which as dry-mix sulfur-lime, concocted in 1922 by A. J. Farley of the New Jersey Agricultural Experiment Station, share the popularity with self-boiled lime-sulfur as fungicides for stone-fruits, while colloidal sulfur, a very finely divided form of sulfur, is just now attracting considerable attention, having been brought to the attention of the scientists by H. C. Young, of the Ohio Agricultural Experiment Station in 1924.

COPPER SPRAYS

Copper sprays have no ancient historical background. W. F. Radclyffe tried copper sulfate on roses to control mildew in 1861, but burned the foliage. Real progress with copper sprays was stimulated by the introduction of downy-mildew of the grape from America to France. Sulfur was found to be of no value against this disease, and only the discovery of bordeaux mixture saved the European grape industry.

The events which led to the discovery of bordeaux mixture are unique. Along the highways near St. Julien, Margaux, and Pauillac, in the Medoc, the growers suffered considerable loss each year from pilfering. It had long been the custom to douse the rows near the highways with verdigris solution to give the fruit the appearance of being poisoned. In many cases a mixture of lime and copper sulfate was substituted for the verdigris on account of economy. A. Millardet of the Academy of Sciences, Bordeaux, reported in 1882 that the vines which had been so treated retained their foliage, while those farther from the road were defoliated. Millardet and Prillieux soon ascribed the control to the copper sulfate in the mixture, lime alone having been tried long before, and found to be ineffective against the mildew. Millardet receives the most credit for the discovery as he continued the experimental work with these materials, being assisted by U. Gayon, professor of chemistry of the Academy of Sciences of Bordeaux. They called their material "bouillie bordelaise."

Bouillie bordelaise, or bordeaux mixture, was soon found to be an effective fungicide on potatoes, tomatoes, and many other crops. The formula underwent many changes before reaching the present-day 4-4-50 mixture, but the active principle—copper in a colloidal form—has remained unchanged. It was introduced into the United States in 1885 by F. Lamson-Scribner, United States Department of Agriculture. W. J. Green of the Ohio Agricultural Experiment Station was

probably the first to use it on fruit-trees, applying it to cherries to control leaf-spot, in 1890.

Bordeaux mixture was first applied as a dust by G. C. Johnson, Kansas City, about 1900. Copper-lime dusts have since been considerably improved and have a certain range of usefulness for protecting vegetable crops. In 1925 and 1926 colloidal copper materials, made of copper hydroxid or copper salts in extremely fine state of division, have received attention, and show considerable promise.

STOMACH POISONS

The ancients did not use stomach poisons in controlling insects. Paris green did not appear until some time between 1860 and 1870. According to the Prairie Farmer, the Galena (Illinois) Gazette for June 1869 reports that George Liddle, Sr., used it for the Colorado potato-beetle in 1868. Whether or not Liddle was the first to use it, the practice doubtless began in the western states, where the potato-beetle first became serious. In 1872 Le Baron, State Entomologist of Illinois, recommended spraying apples trees with paris green to prevent injury by spring canker-worms, and the first authentic report of its use against codlin-moth is in 1878, and it cites E. P. Haynes, Hess Road, Niagara County, New York, as having found trees sprayed for canker-worm less subject to damage by codlin-moth.

London purple, a calcium-arsenic compound, appeared in 1878 and calcium arsenite between 1890 and 1900. The originator of calcium arsenate is not known, but S. U. Pickering, of the Woburn Experimental Fruit Farms, England, used it successfully in 1908. Considerable impetus was given by the spread of the cotton boll-weevil in the South, where it has been the chief arsenical poison in use since 1920.

Lead arsenate paste was introduced as an insecticide in 1892 by F. C. Moulton, of Malden, Massachusetts, a chemist with the Gypsy Moth Commission. Paris green and other

arsenicals hitherto used caused so much burning on foliage and fruit that the need of a safer arsenical was plainly seen. Powdered lead arsenate was on the market as early as 1903, but it did not come into general use until 1910 when A. C. Morgan of the Tennessee Agricultural Experiment Station employed it as a dust on tobacco. Now the lead arsenates are the most widely used stomach poisons on the market.

Other stomach poisons have since been discovered, but have not found wide application. Sodium fluosilicate was recently given prominence by S. Marcovitch, of the Tennessee Agricultural Experiment Station, who recommended it for combating the Mexican bean-beetle. It had been used as an insecticide as early as 1896 by an Englishman named Higbee. Barium carbonate and sodium and calcium fluorid have also been introduced recently.

OIL SPRAYS

Goeze, in 1763, wrote: "Petroleum, turpentine, and other oils are also recommended, but care must be taken in their use, since they also act upon the plants, making them sick and even killing them." The same observations pertain today. Forsythe recommended whale-oil as a scalecide about 1800. Kerosene emulsion was first employed as a spray against the currant-worm, Henry Bird, of Newark, New Jersey, using a mixture of kerosene, soap, and water in 1868. The Hubbard-Riley formula, published in 1874, requiring two gallons of kerosene, one gallon of water and one-half pound of soap was the standard oil spray until about 1905, when the present-day oil emulsions and miscible oils appeared. Pickering of Woburn, England, and C. A. Penny, of the Delaware Agricultural Experiment Station, made sprays from a wide variety of oils. The B. G. Pratt Company, of Hackensack, New Jersey, introduced Scalecide in that year.

About 1920 the great increase of San José scale in the Middle West revived the interest in lubricating oil sprays,

and several simplified formulæ for their manufacture appeared, notably those of A. M. Burroughs and W. M. Grube, of the Missouri Agricultural Experiment Station in 1923, and A. L. Melander, A. Spuler, and E. S. Green, of the Washington State Agricultural Experiment Station, in 1924 and 1926.

NICOTINE SPRAYS

It was not long after Sir Walter Raleigh introduced tobacco to European smokers that it became of note as an insecticide. It was reported in the papers of Marseilles in 1763 that a solution made of finely ground bad tobacco would kill aphis, while Goeze, in 1787, proposed the use of the dry ground powder, thus furnishing historical background for the nicotine dusts. In 1885 a solution called "Gold Leaf Tobacco Extract" was put on the market, a fore-runner of the Black-leaf "40" and other nicotine sulfate extracts.

DUSTING

While the ancients threw ashes, lime, dust, and other materials on plants as a protection, the earliest use of dusts was the application of sulfur to grapes in America, to control powdery-mildew. According to J. Fiske Allen, this treatment was common in this country as early as 1848. G. C. Johnson of Kansas City put a machine and materials for dusting plants on the market in 1900, but it was not successful. F. M. Blodgett revived interest in this method of application and published from the Geneva (N. Y.) Station in 1914, and his work, with that of Donald Reddick, Cyrus Crosby and H. H. Whetzel, and of the Niagara Sprayer Company of Middleport, New York, have been responsible largely for the high state of efficiency reached in dusting practice today. The addition of tobacco dusts about 1919 and calcium cyanid dusts in 1925 for control of sucking insects were marked advances.

Dusting machinery has been vastly improved. Larger

fans, more powerful engines, and self-mixing attachments have made this method of control more satisfactory.

Airplanes had been used as early as 1921 for dusting forest trees in Ohio. The practice spread to the dusting of cotton for boll-weevil, and over 50,000 acres were covered by this means in 1925, while in the same season large acreages of peaches in Georgia, apples in Oregon, and cranberries in New Jersey were dusted experimentally.

SPRAYING MACHINERY

The whisk-broom, in use in France as late as 1880, was the forerunner of the modern sprayer. The next step was the watering-can with a nozzle punched full of holes. The

FIG. 1.—The first successful spraying outfit using steam power.

syringe, in reality a small hand-pump, the garden engine, a misnomer to the extent that no engine was connected with it, and the knapsack sprayer, flourished in the '70s and '80s. The first traction sprayer was designed by the Nixon Nozzle and Machine Company, Dayton, Ohio, in 1887. In 1894

power-sprayers appeared simultaneously in California and Connecticut, a steam engine furnishing power for each. (Fig. 1.) N. B. Pierce, of the United States Department of Agriculture, reporting work done in California in 1894 and 1895 on peach leaf-curl, calls attention to gas-engine sprayers manufactured by the Union Gas Engine Company, San Francisco, and H. R. Gunnis, San Diego. About 1900 the first complete power-sprayers operated by gasoline engines appeared on the market. (Fig. 2.)

Probably the greatest single improvement made in power-sprayer equipment was the perfection of the modern pressure regulator by the Bean Spray Pump Company, Lansing, Michigan, in 1911. The introduction of the spray-gun in 1914, by the Friend Sprayer Company, Gasport, New York, to match in speed some of the work done by dusting machines, was another big advance. In 1925 the liqui-duster, which blows a spray onto the plants by means of a blast of air from a fan-blower, was put on the market by the Rex Company, Rochester, New York.

The needs of the dooryard gardener have not been ignored. Light powerful hand-sprayers and fan and bellows (puffer) dusters have been designed, which are particularly satisfactory for use on a few plants.

A complete history of the rise of spraying in America would make very interesting reading. Taken step by step it has been a slow process, with a fair quota of ludicrous mistakes and not a few misconceptions, but when the perspective of time allows a full view it is seen as a period of great achievement, during which remarkable ingenuity and perseverance were being constantly exercised. S. W. Fletcher has summed up the situation adequately in a manuscript yet unpublished:

"When John Josselyn visited New England in 1639 he was treated with 'Half a score of very fair Pippins' which had been harvested from trees planted by Governor Endicott on Gov-

ernors' Island, Boston Harbor; but he says there was 'not one apple tree, nor pear, planted yet in no part of the country but upon that island.' On a second visit to New England, however, in 1671, he found the country 'replenished with fair and large orchards. . . . Our fruit trees prosper abundantly—apple trees, pear trees, quince trees, barberry trees.' In these latter days of increasingly intricate and laborious spraying programs, his

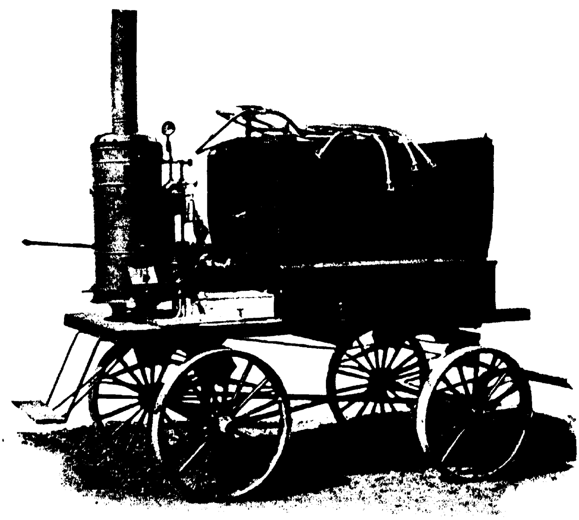


Fig. 2.—Power-sprayer of early type, put on the markets in the 90's by the Field Force Pump Company. Steam power was used.

description of conditions in colonial times is enticing. He says, 'Their fruit trees are subject to two diseases, the meazles which is when they are burned and scortched with the Sun; and lowsiness, when the woodpeckers jab holes in their bark; the way to cure them when they are lowsie is to bore a hole in the main root with an Augur and pour in a quantity of Brandie or Rhum and then stop it up with a pin made of the

same Tree.' The simplicity of this treatment, if effective, commends it to the harassed fruit-grower today.

"Previous to 1880, there was practically no spraying of orchards. In colonial days, when the fruit was grown mainly to drink, sundry blemishes and even a few worms did not detract materially from the value of the ultimate product. Only when there arose the idea of growing fruit primarily for dessert purposes, and especially for market, about 1860, was attention directed to 'faulty' fruit, which hitherto had been considered more or less of an unescapable act of Providence. Our grandfathers, we remember, were prone to boast of the fine fruit produced in their youthful days, without spraying. Undoubtedly there were fewer pests and smaller losses than now. Peaches, especially, were grown to perfection without the handicap of yellows, borer and other pests, until about 1870. Orchards were fewer and farther apart, so that the pasturage for insects and diseases was not only more restricted, but also more difficult of access. Yet we may fairly assume that the main difference is in the higher standard that now prevails as to what constituted 'good fruit.'

"The rapid expansion of apple orchards between 1850 and 1870 particularly in western New York, was followed by increasing loss from the depredations of the codlin-moth, canker-worm and other pests. No practical remedy was known. Many orchardists became discouraged; about 1880 some began to cut down their trees. . . .

"By 1885, spraying with Paris green for codlin-moth, canker-worm and tent-caterpillar was common throughout western New York. Spraying did not receive general recognition, however, until after 1887, when the newly organized experiment stations began to acquire experimental evidence.

"Spraying for the control of fungous diseases became established between 1885 and 1895, following the discovery of Bordeaux mixture by M. Millardet, in 1882. Announcement of the efficiency of 'Bouillie Bordelaise' was made in France in 1885, and in America the following year. Bordeaux, in several modified formulæ, continues to be a standard fungicide, but was largely supplanted by lime sulphur in orchard spraying, about 1890, because of the increasing complaint that Bordeaux burns the leaves and russets the fruit. Other high points in our spraying history are the development of self-boiled lime sulphur, about 1907, by W. M. Scott, just in time to save

the peach industry of the South from extinction by brown-rot; and the advent of dusting, about 1912, in which the chemicals are applied dry, instead of in water.

"The decade between 1890 and 1900 developed conclusive evidence that the treatment of orchards with fungicides and insecticides, combined, could be expected to control orchard pests. This at once put fruit-growing on a more stable basis than ever before; even the great San José scale scare of 1895-1905 did not seriously undermine that faith. It is with us today, a bulwark against the ever-increasing number of orchard pests, native and introduced.

"The rapidity with which spraying has become established in horticultural practices is quite remarkable. Fifty years ago, spraying was practically unknown; now it is universally recognized as essential to success. Improvements in machinery, materials and methods follow each other so rapidly that the commercial practice may change completely in less than a decade. Orchard spraying is distinctly American; no other country places anywhere near as much emphasis on this method of controlling orchard pests."

CHAPTER II

PRINCIPLES UNDERLYING SPRAYING PRACTICES

KNOWLEDGE of the habits of the pests of the farm, orchard, and garden is essential if one is to proceed intelligently toward their control. A wide diversity is seen in the nature of the injury, method of attack, and life cycles of the various insects and diseases, each one usually presenting some angle from which the grower may best begin with his protective or combative measures. Until the organism doing the damage is somewhat understood, attempts at control are only guesswork.

Therefore there has been built up around the art of spraying a great fund of scientific information, to which the entomologist, plant pathologist, chemist, engineer, botanist, and grower himself have contributed. The entomologist and plant pathologist have studied the life histories of most of the insects and diseases with which the farmer has to contend, pointing out the most feasible means of preventing the injury which these are doing; the chemist has compounded mixtures of toxic or preventive nature which will ward off the troubles or kill the causal organisms, leaving the plant unharmed; the engineer has designed machinery with which to apply insecticides and fungicides; the plant-breeder has found or developed strains of plants which are resistant to the attacks of certain pests; while the grower has armed himself with many farm practices and homely weapons, and has furnished the materials with which the others worked.

It will be seen that many remedies consist in the application of simple farm practices, such as the rotation of crops to check the corn root-worm or club-root of cabbage, the plowing of barrier furrows to stem the advance of the army-

worm, and the use of disease-resistant varieties. All these methods are exceedingly valuable and are of themselves occasionally sufficiently effective. Nevertheless, the chief reliance at this time must be put in spraying with protective, toxic, or repellent materials. To do this, a grower must have at least a superficial knowledge of insects and diseases, if he is to do more than blindly follow the recommendations of experiment stations and investigators. Inasmuch as local factors alter the practicability of many of the control measures suggested, it is highly desirable that every farmer understand at least a few of the fundamentals underlying insect and disease control so that he can exercise judgment in undertaking combative measures.

Several factors are important in controlling insect and disease outbreaks. Some of these are: (1) Natural enemies and introduction of parasites; (2) climatic conditions; (3) sanitary measures and farm practices; (4) mechanical measures; (5) insecticides; (6) fungicides; (7) resistant varieties and stocks.

NATURAL ENEMIES AND INTRODUCTION OF PARASITES

This method pertains entirely to the control of insects. Were it not for the vast army of natural enemies to injurious insects, plant life would have a difficult struggle in order to exist. However, almost all insects have certain foes which usually increase in proportion to the prevalence of the host and which are quite effective in keeping it in check. Unfortunately this is not true of all insects. The most troublesome ones seem to have insufficient foes. The potato-beetle, codlin-moth, curculio, cabbage-maggot, striped cucumber-beetle, and many other common pests cannot be left at this time to natural enemies. Only constant and thorough spraying will avail to protect fruits and vegetables from their ravages. On the other hand, the army-worm, San José scale, tent-caterpillar, and many other insects appear in cycles, usually increas-

ing very rapidly, while the parasites and other natural enemies are rather tardy about taking up the chase. However, the insects are eventually overtaken and reduced and sometimes almost exterminated, resulting in a period of years when they are perhaps only slightly troublesome. This dearth of host starves the natural enemies until finally the host again commences its ascendancy and the cycle is repeated.

Great inroads are made by birds and animals. Quail, pheasants, woodpeckers, swallows, and many others eat enormous numbers of insects, depending upon them largely for their food supply. The mobility of birds enables them to flock to the most heavily infested areas, thus reducing the insects where reduction is most needed. Toads and frogs eat large numbers of insects, while rodents also help to keep them under control. Even fish, such as the kille fish, which prey upon the larvæ of the mosquito, play their part.

An example of the way in which parasites operate to keep down insects is the case of the San José scale which is attacked by at least nine species of Hymenoptera, a dozen ladybird beetles, several fungi, and other diseases. A few years ago the San José scale was the greatest menace to the fruit industry, wiping out thousands of acres of orchards before the advent of parasites and effective spray materials enabled the growers to control it. Since about 1905 scale has been on the decline, reaching the stage about 1915 where it was not considered a pest of large importance in many districts. This scarcity caused a great reduction in the ranks of its parasites. However, since about 1920 scale has been on the increase, especially in the Middle West, and spraying with mixtures which formerly proved effective has not controlled the outbreaks in some sections, and new sprays are being sought with which to fight it. Now that this scale is on the increase, one may confidently expect the parasites to increase, which, combined with more thorough spraying practices, will keep the scale under complete control.

A parasitic insect lays eggs in the body of the tomato-worm, resulting in the death of that host. The Japanese beetle, on the Atlantic Coast, promises to give way before the attacks of a parasite which lays eggs on the body of the female beetle. Fungous diseases also play an important part. Flies are killed in large numbers in the fall when they may be seen, covered with a powdery substance, clinging to the ceiling. Tent-caterpillars are preyed upon by both fungous diseases and a bacteria which causes the worms to die. Artificial introduction of parasites into heavily infested districts is practiced, but frequently fails because of certain differences in climate which cause the parasites to die. In California ladybird beetles which feed on certain citrus scale are successfully transported long distances to the infested groves, but this practice is not very general.

While natural enemies are important in reducing orchard pests, they do not offer a sufficiently effective barrier against them. Morrill and Back [1] found, for example, that although every effort had been made to introduce and maintain fungous parasites of the white-fly in Florida, only about one-third of a complete remedy could be counted on over a period of years. Therefore, other measures of control are necessary.

CLIMATIC CONDITIONS

Weather and environment are important factors in the prevalence of insects and diseases. In certain localities it may be especially difficult to control certain pests because conditions seem to be more favorable to their development than in even near-by localities where perhaps different elevation or exposures may markedly influence the climate. Temperature and moisture are probably the two most important elements.

Low temperatures frequently greatly reduce insect prevalence. San José scale has been practically wiped out of cer-

[1] Morrill, A. W., and Back, E. A., U. S. Bur. Ent. Bull. 102. 1912.

tain areas by the recurrence of winters during which extremely low temperatures prevailed. Aphis are sometimes greatly reduced by freezes just at the time they are hatching in the early spring, while in some warm districts where there are several broods of codlin-moth the larvæ emerge continually throughout the summer instead of hatching in one or two definitely timed broods as they do in colder regions, thus

Fig. 3.—Spraying burning oil on hedgerows to control gipsy-moths.

making control measures far more difficult. Bitter-rot of apple is found in the warm moist areas in the South, and becomes almost unknown in the cold northern latitudes. Apple-scab is more prevalent in moist areas than in dry climates, while sooty-blotch will develop on apple trees in the floor of a valley but may be almost unknown even a mile or two away at an elevation only a hundred feet or so above the floor. The grower cannot control climate. He can, how-

ever, select varieties which are best suited to the peculiarities of the particular section, paying special attention to getting those which are the least troubled by the pests most prevalent there. Thus his spraying bill may be somewhat reduced.

SANITARY MEASURES AND FARM PRACTICES

A great opportunity for the farmer to cut down the inroads made by insects and diseases is through sanitary measures and farm practices. The cleaning up of hedges and fence-rows (Fig. 3), and the burning of brush lands and even the leaves and trash along the edges of woodlands, where it can be done without endangering the trees, will kill many insect pests, while the removal of crop remnants and the proper storage of grains frequently prevent the carrying over of pests to the following year. It is a well-known fact that the plum- and apple-curculio winter over in rubbish in the orchard. If these sources of infestation are cleaned up, there will be less curculio to be controlled by spraying. Severe infestations of codlin-moth can be combated successfully only by supplementing spraying with banding of trees with burlap bands, to catch larvæ, picking up and destroying wormy apples, disinfection of storage containers to kill hibernating larvæ, and scraping the rough bark from the trunk and large branches in the late winter, to remove the larvæ from their over-winter hiding places. Mummified fruits on peach, plum, and cherry trees carry over brown-rot, and their removal will reduce possibilities of infection the following season.

The removal of crop remnants is of the greatest importance in the control of vegetable diseases. Bacterial leaf-spot and black-rot of cabbage, pea root-rot, and soft-rot and stem-end rot of melons are a few familiar examples of serious vegetable troubles which can only be controlled by destroying all remnants of the crop which remain in the field after harvest. With some of these diseases it is even unsafe to feed the

remnants to stock, lest the organism be returned to the soil through manure. Burning is the safest method of destroying such remnants.

Crop rotation reduces insect and disease attacks. The planting of one crop year after year on the same ground usually allows the insect pests to multiply on that area until finally production becomes unprofitable. The corn root-worm is an example of this. It can only be stamped out by keeping corn from the land for a number of years. The cotton boll-weevil is another example, a rotation of crops resulting in a reduction of the number of weevils on the ground. For the same reason certain crops should not follow one another, if one harbors an insect or disease which attacks the following crop. Strawberries should never follow sod or grass on land, because of the danger of damage by June-beetle larvæ. Crown-gall on nursery stock, club-root of cabbage, and the cabbage-maggot are reduced by crop rotation. Crop rotation is not possible with fruit-trees, grapes, currants, and gooseberries, and is only partially possible with berries. This perhaps accounts in a measure for the important developments in spraying these plants, while spraying practices for vegetables and annual crops have not become as important as the other methods of insect and disease control.

The use of trap crops to collect insects, where they can be killed readily, thus keeping them away from the main or money crop, is another common farm practice, especially in fighting vegetable pests.such as the melon-worm and cucumber-beetle. In controlling the latter, a border of squash vines is planted around the melon patch a short time before the melons are planted. The cucumber-beetles concentrate on the earlier squash vines and are easily killed, leaving the melon field fairly free of this pest.

Fall or early spring plowing, which results in the destruction of many of the larvæ, such as the oriental fruit-moth, and summer plowing, in the case of the grape-vine root-borer and

pear-midge, are still other methods of insect control. The running of poultry in the asparagus bed or potato patch and plum or peach orchard, to kill the asparagus-beetle, flea-beetle, and curculio, is a practice of common knowledge. Lastly, fertilization and cultivation which stimulate growth may enable plants to resist the attacks of some insects and diseases and yield good crops in spite of these enemies. With some pests this is the only known method of control. Bacterial blight of the peach and the fruit-tree bark-beetle are two troubles usually controlled in this way, while the injury done by cucumber-beetles may be greatly lessened if the vegetables which they attack are stimulated into vigorous growth.

MECHANICAL MEASURES

This fourth method of controlling insects and diseases is possibly the oldest and is still one of the most important, although it has naturally undergone much limitation. With some troubles plant removal is the only known control. Yellows and little-peach, two of the most serious and widely distributed troubles affecting the peach, orange-rust of the blackberry, fire-blight on pears and apples, dead-arm of grape, and mosaic and spindle-sprout of potatoes are examples of this in treating disease. The control of the various cane-borers by the removal of affected canes, the cutting out of round- and flat-headed apple-tree borers, and the covering of melon plants to prevent the attacks of the striped cucumber-beetle are the only practical methods of controlling these insects.

Mechanical control methods are optional with spraying in keeping down attacks of other pests. Climbing cutworms, Colorado potato-beetles, green currant-worms, tomato-worms, and Japanese beetles are frequently hand-picked in small garden patches where spraying would be too troublesome, while the tents of the tent-caterpillar are usually burned with a kerosene torch or removed by hand and the contents trampled

upon. Some mechanical methods have been entirely superseded by spraying. Curculio are now kept in check by spraying instead of by the old method of jarring the trees, and the gathering of peach and plum mummies in the winter is no longer considered essential to the control of brown-rot.

The rogueing of fields to remove diseased plants is steadily becoming of greater importance, especially where pure clean seed strains are developed. In this way blue-stem, curly-dwarf, leaf-roll, and other diseases of the potato which are transmitted through seed are controlled, these troubles not yielding to spray treatments during the growing season.

Many other mechanical practices are carried out as auxiliaries to spraying. Codlin-moth larvæ are trapped beneath bands and destroyed. Egg-masses of the gypsy-moth and tent-caterpillar are collected in the winter and spring. During the two years of heavy infestations by tent-caterpillars in New Jersey in 1924 and 1925, the aid of the Boy Scouts, and in some sections of the school children, was enlisted in collecting egg-masses before they hatched, resulting in a considerable reduction in the number of the caterpillars, while the children received financial reward for the egg-masses brought in. Grapes are bagged to protect them from the berry-moth; trees are banded to prevent the ascent of the spring and fall canker-worm; and barrier furrows are plowed around fields to stop the invasions of army-worms.

INSECTICIDES

Insect pests are usually combated with insecticides. For proper use of materials a knowledge must be attained of the way in which the damage is done to the host.

From the standpoint of insect control there are three types of insects: biting insects, which devour stems, foliage, or fruit; sucking insects, which insert a long proboscis or beak into the tissues of the plant, sucking out the juices; and lapping insects,

which lick moisture from the surface of the leaves with a proboscis. Many of these biting insects, such as the cane-borers and oriental fruit-moth, cannot be killed with insecticides because they do their work in protected places. However, even where the insects can be reached, different insecticides must be used to control these various kinds of insects. The common classes of insecticides are stomach poisons, contact insecticides, gases, and repellents. Some materials act in more than one capacity. Lead arsenate is both a stomach poison and a repellent to the Japanese beetle and it has some fungicidal value as well. Sodium fluosilicate, a new stomach poison, acts as a contact insecticide in a very peculiar way. It irritates the feet of the Mexican bean-beetle, and the insect attempts to clean its feet in its mouth, getting a sufficient amount of the poison in this manner to be killed.

Stomach poisons

Stomach poisons are usually arsenicals, applied in a liquid or dust form so that in feeding upon them the insects will be killed. They are only effective against insects with biting or lapping mouth-parts, which swallow the tissues as they remove them or which lap up the moisture from the surface, such as the fly of the apple-maggot and the cherry fruit-fly. Some insects, such as the oriental fruit-moth, carefully lay aside poison-covered tissues and feed on the clean tissues underneath. Most sucking insects thrust the mouth-parts through the coating of poison and feed on the juices inside the leaves without being injured. Arsenical spray materials have been many and various. Lead arsenate, both dry and paste, has been the standard stomach poison for twenty-five years. Calcium arsenate is used principally on cotton. New materials are constantly appearing, such as sodium fluosilicate which is now used against the Mexican bean-beetle. However, as late as 1927, lead arsenate, paris green, and calcium arsenate were the most common stomach poisons. Hellebore is an organic

stomach poison made from the powdered root of the white hellebore plant. It is toxic to insects without being dangerous to man or to domestic animals.

The poison must be applied before the insect does the damage. This necessitates a knowledge of its life history. All spray schedules are based on careful observation of the habits of insects, and coatings of poison are maintained on the plant over the period during which the pest would normally be injurious. Many common insects have several broods and frequent spraying during the entire period of emergence is necessary for effective control.

Contact insecticides

These either clog the respiratory organs, causing suffocation, paralyze the nervous system, act as narcotics, anesthetics, or toxins, or else corrode the skin or covering of the insect, thus causing death. They are used always against sucking insects because the latter cannot be controlled with arsenicals, due to the peculiar method of feeding. Corrosive materials are seldom employed except in the dormant season, because, as most insects are covered with a chitinous or horny skin, any material powerful enough to penetrate this covering would be likely to injure the fruit or foliage. Concentrated lime-sulfur is highly corrosive when used in winter strength, but the summer-strength solution is only slightly effective as a contact insecticide. The sprays which clog the breathing organs are more effective and safer. To be effective it must be remembered that, in general, contact insecticides must come in contact with the insect, and coating the foliage and fruit will not give control. An exception to this is nicotine when applied as a dust. It gives off a gas and need not be applied directly upon the insect itself. When applied as a dust in a lime or clay carrier, the gas is considered to be the effective agent, and it may not be necessary actually to coat the insect with it. This is illustrated in the killing of the

striped cucumber-beetle, which has a hard shell. The fumes cause paralysis or suffocation. In any case, a thorough even application or distribution of the material gives better control than careless methods.

Nicotine sulfate, miscible oils, oil emulsions, and soap solutions are the most common contact insecticides. Nicotine sulfate is put up in many forms, but the liquid 40 per cent solution is the most general, and it is on the market under several trade names. This is a very powerful contact insecticide and it is diluted as greatly as 1 to 800 parts or even 1 to 1,000 parts of water before being applied. Oil sprays are very popular for dormant use at which time scale insects, eggs of the European red-mite, hatched aphis, and, to a certain degree, aphis eggs can be controlled. The oil is mixed with soapy water or with calcium caseinate, saponin, or other flux to form a stock emulsion or miscible oil of known strength and this is later diluted before application to the tree. Kerosene, crude petroleum, lubricating oil, and many other oils form the basis of oil sprays.

Soap solutions have been used for two or three hundred years, being one of the original spray materials. The common sources of soap solutions are whale-oil or fish-oil soap, although any good soap is an effective insecticide for aphis and for some soft-bodied larvæ. For use in very small quantities, common laundry soap at the rate of ½ pound to a gallon of water is an excellent remedy for insects on house plants. These soaps are also used with water in making various oil emulsions, as water will not readily mix with oil unless soap is employed as a flux.

Sulfur in the form of polysulfids of calcium (concentrated lime-sulfur) is a very effective contact insecticide and is used largely for dormant spraying for the control of scale.

Pyrethrum, buhach and Dalmatian powder are contact insecticides with the peculiar property of giving off gases which paralyze or asphyxiate the insects, yet are not sufficiently

concentrated to be dangerous to domestic animals or man. They are made from certain forms of chrysanthemums and are used as a dry powder, pure or diluted with flour or lime, or mixed as a spray. They deteriorate rapidly on exposure to air.

Fumigants and gases

This class contains many of the most effective methods of crop pest control. While primarily used for warfare against insects, gases are powerful agencies for the treatment of seeds to destroy fungous spores, such as stinking-smut of wheat, scab and black-leg of potatoes, and loose-smut on oats. Materials in this class are used against certain scale insects on citrus fruits which will not yield to any practical spraying treatment, against borers in the roots of trees, against insect and disease pests in greenhouses and forcing houses, against weevils, rodents, and other pests in granaries, mills, storehouses, and dwellings, and also to control insects and fungi infesting seed-beds and even broadfield crops, lawns, and golf courses.

Carbon bisulfid, hydrocyanic-acid gas, calcium cyanid, formaldehyde, nicotine, sulfur, and paradichlorobenzene are among the most deadly and effective materials in this group. The first two are largely used in the fumigation of warehouses, mills, and granaries, while the second is employed as a fumigant for citrus trees. Formaldehyde is used widely in seed treatment and soil sterilization, while nicotine and sulfur are prominent as fumigants in greenhouses to destroy plant-lice and other insects and to control diseases. Carbon bisulfid is also used in destroying ground-hogs, woodchucks, rabbits, squirrels, and other pests in their burrows, and in killing insects on nursery stock. Paradichlorobenzene is one of the newer fumigants and has lately been developed as a control for the peach and plum root-borers, and it offers promise as a material which may in the future be employed to control

borers in apple trees and other plants. Hot water and steam are used in soil sterilization and must be included in this class.

Generally speaking, fumigation is practiced more extensively for controlling insect and rodent pests than against fungous troubles. It is used more indoors than out, except in the control of citrus scale where it is very widely employed outdoors. It is little used in controlling vegetable pests, except those in greenhouses, hotbeds, coldframes, or forcing houses, where fumigation becomes one of the most effective weapons in the hands of the gardener.

Repellents

Certain materials have properties which make them unpalatable or annoying to insects. These are called repellents. Lime, bordeaux mixture, carbolic acid, naphthalene, lead arsenate, self-boiled lime-sulfur, whitewash, tobacco dust, and even, according to Sanderson, common road dust are among these. Some insects are especially sensitive to particular substances. It was found at the Japanese Beetle Laboratory at Riverton, New Jersey, that geraniol, a fragrant oil secured from geranium, exercised a most powerful attractive effect on the Japanese beetles, and they would fly considerable distances to reach and feed on materials containing that substance. The potato flea-beetle will not injure plants sprayed with bordeaux mixture, while the rose-chafer will avoid plants sprayed with self-boiled lime-sulfur. Borers will not attack trunks of trees as readily if the trunks have been whitewashed.

Repellents have one or more of three common properties which probably account for their effectiveness; i.e., odor, color, or possibly flavor, or combinations of these. Lime, whitewash, and self-boiled lime-sulfur leave a white coating on plants to which they are applied. Naphthalene, carbolic acid, and tobacco have a powerful odor. It is patently impossible to determine the effect of flavor on insects.

Some repellents have other insecticidal values. Lead

arsenate is not only a repellent but a powerful stomach poison. Tobacco acts as both a stomach poison and contact insecticide.

Another class of repellents has physical qualities which make it effective. Sticky bands which are placed on trees to keep caterpillars away, or "Tanglefoot" and similar fly-papers, contain these properties.

FUNGICIDES

The fungi comprise the molds, mildews, rusts, smuts, and several others. Those which trouble the gardener gain a foothold on his cultivated plants, and weaken or disfigure them by living on them parasitically. They are particularly difficult to combat because the spores by which they are spread are microscopic in size, and therefore the attack of the fungus goes unnoticed until it has gained a foothold and is difficult to dislodge. Fungous troubles differ markedly from insect attacks in that they must be prevented, not remedied. The protective coating of spray must be applied in advance of the arrival of the spores so that when they alight on the foliage or fruit they will find a toxic substance there which will prevent germination. This point cannot be too strongly emphasized.

Fungicides are materials which will kill fungous spores or prevent their germination. The principal materials used in making fungicides are sulfur and copper. These, in combination with lime, form the bulk of common sprays, such as bordeaux mixture, Pickering spray, Burgundy mixture, and ammoniacal copper carbonate among the copper fungicides, and lime-sulfur solution, self-boiled lime-sulfur, wettable sulfurs, atomic sulfur, and colloidal sulfur among the sulfur fungicides.

The copper sprays are in general the more powerful fungicides and are, therefore, employed wherever possible. However, they are toxic to some fruit and foliage, such as that of the peach, so cannot be used except where the fungous

pest to be combated will not yield to sulfur sprays, and then only when the ravages of the disease cause greater loss than the injury or burning by the spray material. A notable example of this is the spraying of apples for control of bitter-rot. This disease is prevalent in many localities in the east-

FIG. 4.—Results of spraying potatoes for control of late blight. Unsprayed plants in alternating four-row blocks have died. Spray should be applied before blight appears.

ern half of the United States and cannot be controlled by sulfur sprays. Therefore, bordeaux mixture must be used. In some sections, this frequently burns the foliage seriously and russets the fruit, greatly reducing its commercial value, but the loss from this source is much less than the normal loss from bitter-rot were bordeaux sprays not used. The

foliage of field crops, such as potatoes (Fig. 4), tomatoes, melons, is not damaged by bordeaux mixture and it is here that this material gains its widest utility.

On more tender plant tissues the sulfur fungicides are used. Concentrated lime-sulfur is too caustic for some plants such as the peach and in some sections on certain varieties of apples, and on these the less caustic self-boiled lime-sulfur and wettable sulfurs are used.

For best control of fungous diseases observations must be made of the spore formation in order to determine when to spray. Patently this is not possible on the farm or in the garden, and because of this spray schedules are made out to cover average or bad seasons. In many states the agricultural college or experiment station makes progressive observations on the development of both diseases and insects during each season, so that notice may be sent to growers when it is time to spray. The importance of these observations can be estimated by the experience in New Jersey, in 1925, when it was found that in all of the big commercial fruit sections in the southern and central parts of the state the apple-scab spores did not mature until about the time of the petal-fall spray, making the use of lime-sulfur in the pre-pink-bud and pink-bud stages unnecessary. The petal-fall spray was the critical spray for apple-scab in those districts. At the same time, in the extreme northern and higher part of the state where the season was almost three weeks behind these other districts, the scab spores matured only a few days later than in the southern districts, making a pre-pink-bud application of lime-sulfur essential if scab was to be controlled, the trees in the northern section being just at that time in the pre-pink-bud stage.

Another essential feature in controlling fungous pests is the application of the spray material in advance of rain-storms. Moisture is required for the discharge and germination of most spores. It is during protracted rain-storms that the

apple-scab infection takes place and sprays applied after rain-storms are far less effective than those in advance of the rainy period. When important fungous diseases, such as apple-scab are to be combated, a sharp lookout should be maintained for approaching storms and weather forecasts should be carefully studied, and protecting coatings of fungicides should be applied before the rainy spell arrives. This is one of the factors favoring applications of dust materials, which can be put on with far greater rapidity than can liquid sprays. The grower can cover many acres with dust after the storm is in sight, enabling him to protect at least his most susceptible varieties, while few growers of extensive acreages have machinery to cover their orchards with liquid sprays in less than five or six days. It is possible that many would get sufficient equipment to cover their orchards in twenty-four or thirty-six hours if they could afford to maintain teams and men to run them, or if sufficient reliable labor were available.

Many other substances, such as lye, bichlorid of mercury, cyanid of mercury, carbolic acid, creosol, and borax, have a distinct fungicidal value, and are utilized more or less in protecting fruits from fungous attacks. Prunes are dipped in lye solution both to kill fungi and to check the skins to facilitate drying. A 5 per cent borax solution has been shown recently by Fulton and Bowman [1] to have distinct value as a dip for oranges to lessen the loss from blue and green molds, and Barger and Hawkins [2] and the Brogdex Company have perfected the treatment. Fulton has shown that ultra-violet light will kill 99 per cent of the spores of blue-mold at a comparatively low cost. The ultra-violet light treatment has the disadvantage of lacking the residual protective effect contained by a dip or wash which will adhere to the surface

[1] Fulton, H. R., and Bowman, J. J., *Jour. Agr. Res.*, Vol. 28, pp. 961-968. 1924.

[2] Barger, W. R., and Hawkins, L. A., *Jour. Agr. Res.*, Vol. 30, pp. 189-192. 1925.

and remain toxic for a considerable length of time. However, this is an indication of a trend of thought at this time.

RESISTANT VARIETIES AND STOCKS

In this method of insect and disease control lie perhaps the greatest opportunities for successful and economical warfare against pests. Already types of vegetables have been produced which are exceptionally resistant to attacks of certain diseases. The Washington asparagus is a notable example, being resistant to orange-rust. Wisconsin has been one of the heaviest producers of cabbage for many decades. Yellows obtained foothold there and threatened to wipe out the industry, in spite of valiant efforts at controlling the disease through spraying, crop rotation, and other means. The breeding of a yellows-resistant strain, the Danish Ballhead, at the Wisconsin Agricultural Experiment Station, saved the industry, and Wisconsin is still one of the leading states in production of cabbage.

Virginia spinach formed one of the most important crops in the agriculture of that state. Yellows drove the growers out of the business. The Virginia Agricultural Experiment Station worked on the problem and produced Virginia Savoy spinach which is very resistant to yellows, and within a few years the growers were back in the industry as heavily as ever.

In Chapters XXIV to XXXIV it may be noted that many troubles affecting vegetable plants can, as far as present-day knowledge goes, be combated only by the use of resistant varieties: cabbages, like Danish Ballhead, resistant to yellows; melons, like Pollocks 1025, resistant to blight; beans, like Robust, resistant to anthracnose and immune to mosaic; Virginia Savoy spinach, resistant to yellows; tomatoes, like Norton, Marglobe and Norduke, resistant to Fusarium wilt; and Golden Self-Blanching celery, resistant to Fusarium wilt.

Unfortunately, in the selection of varieties of tree-fruits, resistance to diseases and insects has not been considered of

great importance, quality, productiveness, appearance, and vigor being thought paramount. It has possibly been considered that insects and diseases on good varieties could be controlled by artificial means. Thus apples of highest quality, such as McIntosh, Delicious, and Stayman, are extremely susceptible to apple-scab, Jonathan to Jonathan-spot and fire-blight. Starr, an excellent cooking apple grown in New Jersey and Delaware (there frequently attaining a size of three inches by the fourth of July), is so susceptible to fire-blight as to make it unprofitable in other sections, and incurs a loss of possibly 10 per cent of trees in some seasons in New Jersey. LeConte and Kieffer pears are of very low quality, but are resistant to fire-blight and are therefore widely grown. Bartlett, the standard of perfection in pears, cannot be grown commercially in some sections due to the ravages of fire-blight. The production of a pear of Bartlett quality and Kieffer resistance to blight should fire the ambition of the orchardist and plant-breeder.

Nor is the field at all limited. Peach-growing has been impossible in the extreme South due to the ravages of nematodes on the roots, but the use of resistant stocks is carrying the peach to the more southerly latitudes. Phylloxera attacked European grapes to such an extent as to prohibit their growth in the United States, but it was found possible to graft them upon Rupestris St. George and other native stocks, which were not only resistant to the attacks of the insect but which also forced the cions into a strong desirable growth, thus saving the great California grape and raisin industry.

The great difference in the performance of adjoining apple trees with tops of similar size and apparent vigor frequently found in well-kept orchards suggests vast possibilites in the influence of the root on the top. W. G. Klee reported in California in 1893 two varieties of apples which were remarkably resistant to attacks of woolly-aphis, in spite of frequent inocu-

lations with this pest, while in Australia the roots of Northern Spy apples are used for grafting in order to rid the grower of trouble from this pest. Naturally, the use of resistant varieties and rootstocks is a slower process with fruit-trees and other perennials where desirable varieties are difficult to produce, and where such long periods are necessary for determination of results. But the possibilties are present and are being constantly utilized. F. C. Reimer, of the Oregon Branch Agricultural Experiment Station, at Talent, found pear stocks which are resistant to fire-blight, on the branches of which the standard desirable sorts can be grafted, so that in case of a bad outbreak of blight only the tops would be injured, leaving a sound trunk and framework upon which to rebuild. The field for the development of crown-gall-resistant apple roots, root-louse-resistant strawberry plants, borer-resistant peach roots, and many other resistant roots should prove most attractive to any investigator.

CHAPTER III

SPRAYING MATERIALS

NOTWITHSTANDING the varied experiences of the ancient and modern gardeners and fruit-growers with insects and diseases, and the extensive literature on the subject of insecticides and fungicides, the control of pests has not become a simple or entirely standardized practice. The ancients used galbanum, tobacco, and soaps for controlling plant-lice. Tobacco has been the leading aphicide for centuries, yet notwithstanding the fact that nicotine sprays are common standard materials a considerable amount of judgment and experience is necessary for best results. Sulfur has been in more or less continuous use as a spray material for one hundred and fifty years, yet it is impossible to prescribe sulfur for any pest control without a knowledge not only of the pest but of the local conditions such as weather prevailing at the time of spraying. The same is true of copper sprays and arsenicals.

There are many points to consider in selecting spray materials. First, the pests to be combated must be classified accurately. This can be done fairly readily by observing the nature of the injury and by noting a few of the principles discussed in Chapter II. Exact identification is not generally essential, it being sufficient for the practical grower to determine whether the trouble is due to a chewing or a sucking insect, or to a fungus. In some cases an exact identification and some knowledge of life histories and spray practices may save spray materials, as in the case of the leaf-hopper. The grower can readily identify the pest as a sucking insect, and

can prescribe the use of nicotine sprays. A knowledge of the life history of this insect would tell him whether the insect was in the adult or winged stage, and if so, that control measures with liquid sprays are difficult and even impractical. However, most insect pests can be controlled after the evidence of their work is at hand. In combating diseases, more complete identification may be necessary. Bitter-rot and apple-scab make circular black spots on the fruit, which can readily be classified by any gardener as due to fungous trouble. Copper sprays are essential for the former, while sulfur is entirely satisfactory for the latter but ineffectual as a control for the former.

Second, the right material for the pest to be combated must be determined. This knowledge can usually be obtained from the state agricultural college or experiment station, or county agricultural agent if there is one located in the county. These agencies, supported by public funds, should be in a position to give the best information on the materials to be used in any given locality. It is important that their recommendations be closely adhered to. Materials which are satisfactory in some localities are dangerous in others. An example of this may be seen in the successful use of bordeaux mixture on apple foliage and fruit in Virginia and West Virginia, when the same materials would be likely to defoliate the trees in New Jersey, Connecticut, or New York. The methods advocated by these stations are far more likely to give satisfaction than the recommendations made by the manufacturers and distributors of proprietary compounds.

Third, the use of standard materials is very important. There are relatively few standard sprays and a knowledge of these can be mastered easily. These sprays will fit almost every contingency and should always be used. Most of these are on the market as proprietary compounds with guaranteed analyses. However, there are literally hundreds of proprietary compounds on the market, for which great claims are made,

and while many of these claims may be justified the grower is much safer using materials of which he is certain.

These standard materials are manufactured from registered formulæ by chemical companies who are in a position to do it cheaply and properly. While many of the materials can be made on the farm, it is generally safer to buy them ready-made from reliable manufacturers. Tobacco decoctions may be made on the farm, for example, by steeping the stems in either hot or cold water. The product, however, is difficult to test for strength, some batches running strong enough to give control of aphis, while others may be too weak. The saving effected may be considerable, providing high-grade refuse tobacco is used, but the uncertainty of the product makes home manufacture an operation of questionable desirability. Lead arsenate can be made readily on the farm, but the economy effected is doubtful because of the variations in the physical properties of the home-made material. Under present-day laws, inspection is made of commercial products of this kind, and they are more likely to be entirely satisfactory than home-made products. In general, it might be said that it is practicable to make materials at home providing the products can be tested so as to ascertain their strength, and where home manufacture offers sufficient saving to warrant the trouble. Some materials, like home-made miscible-oil emulsions, contain certain definite proportions of the active ingredient in a definite form. If there is no free oil floating on the surface, it is not necessary to test these emulsions.

Fourth, proper combinations are indispensable. Many spray materials are incompatible, such as kerosene emulsion and lime-sulfur, because the latter will break down the emulsion, setting free the kerosene and making a curdled mass which it would be difficult to force through the nozzles and which would burn the foliage. Other combinations, such as atomic sulfur and lead arsenate, are unsafe without the addition of neutralizing lime, as the sulfur and lead react to form lead

sulfid, freeing a certain amount of very toxic arsenious acid.

Fifth, correct dilution is essential. Many materials will burn foliage and russet fruit, and even kill the plants if used too strong. Therefore, all containers for measuring sprays should be accurate and operators should exercise the greatest care in weighing out all ingredients. It is important to note that what is a safe and correct dilution in one part of the country may be highly unsafe in another. For example, oil sprays are frequently applied to foliage in concentrations as strong as 5 per cent in California, while a 2 per cent, or even a 1 per cent, solution would be dangerous on the Atlantic seaboard. Concentrated lime-sulfur can be used fairly safely at dilutions of one part to thirty-five parts of water in the Pacific Northwest on apple foliage, while on the Atlantic coastal plain one to fifty is strong enough to cause serious burning of foliage and russeting of fruit, if certain combinations of humidity and temperature are encountered.

In almost every section of the country studies have been made of the insects and diseases which are common on plants, and this information is available in state and federal bulletins, in special books devoted to these topics, and in the discussions on pages 266 to 497. For all of the widely grown fruits and vegetables, standard spray schedules have been worked out by government investigators, describing the combinations of sprays which may be applied to the plants at certain times during their growth and which will anticipate the attacks of the pests usually troubling that host. These spray schedules are very valuable and much faith may be placed in them.

It must be realized that spraying is affected by local conditions, and careful observation and experience will enable the grower to interpret the spray schedule to obtain the best results. Extreme weather conditions may cause the wise grower to modify the recommended schedules slightly, or variations in conditions in different parts of the orchard or garden

may make slight modifications of the schedules desirable. For instance, certain low-lying areas may be more affected than others by scab and sooty-blotch, necessitating extra applications of materials. Some varieties are more susceptible to the attacks of insects and diseases and may need special attention.

Spray materials may be classified as follows:

1. Insecticides: materials which kill insects by poisoning, suffocation, or paralysis.

2. Repellents: materials which repel or drive away insects because of odor, color, or other disagreeable property.

3. Fungicides: materials which kill fungous plants or spores, or inhibit their growth.

A fourth group might also be considered, apart from the three named above, which would include spreaders, stickers, stabilizers, and any other substances which are combined with the above groups to alter the physical properties of these materials.

CHAPTER IV

SPRAYING MATERIALS—INSECTICIDES

THERE are three classes of insecticides: stomach poisons, which are taken internally by the insect; contact insecticides, which burn the insect, clog the breathing pores, paralyze, asphyxiate it, or act as a narcotic; and gases or fumigants, by which the insect is asphyxiated. There may be some overlapping in this terminology, a fumigant may paralyze an insect in the same way as does the contact insecticide.

STOMACH POISONS

The most common stomach poison is arsenic. White arsenic, the commercial name for arsenious oxid, is the basis for the manufacture of all arsenical sprays.[1] Lead arsenate and paris green are two of the most important. Other stomach poisons, such as strychnine, sodium fluosilicate, and barium carbonate, are used in special instances, the arsenicals being of most widespread application.

Lead arsenates

Lead arsenates are the most widely used of any of the stomach poisons, being the standard for controlling insect pests troubling orchard fruits and also many of the garden insects. They can be used in almost every case in which stomach poisons are required. They are manufactured by oxidizing arsenious oxid (white arsenic) to arsenic oxid, and then combining that material with lead acetate. They are on the market in two well-standardized forms, the acid lead

[1] F. C. Cook and N. E. McIndoo, *Chemical, Physical, and Insecticidal Properties of Arsenicals,* U. S. Dept. Agr. Bull. 1147. 1923.

arsenate ($PbHAsO_4$) and the basic lead arsenate [$Pb_4PbOH(AsO_4)_3$]. The basic lead arsenate is usually in the paste form, and chiefly because of its lower arsenic and high lead contents it is more stable and less likely to burn the foliage. It is weaker in insecticidal properties and slower in its action, and must be used in practically one-third larger quantities than the corresponding acid arsenates of lead. In arid regions, as in some parts of California, it has been found that acid lead arsenate is dangerous when used with very hard or alkaline waters, and basic lead arsenate should always be employed under these circumstances. In general, the hard well-waters in most places throughout the eastern part of the United States are satisfactory with acid lead arsenates. Neither arsenate should be used with soaps, as the soaps break down the lead arsenate, setting free water-soluble arsenic oxid which will cause severe burning to foliage.

Lead arsenate has at least one great advantage over the other arsenicals. It is a very stable product, seldom yielding up free arsenic. Therefore, it may be combined with fungicides with little danger of burning the foliage to which it is applied. Paris green, calcium arsenate, sodium arsenite, and others are less stable and burn foliage more frequently. Lead arsenate is also cheap and readily available.

The analyses always should be examined. Acid lead-arsenate powder should have about 32 per cent arsenic oxid and acid lead-arsenate paste approximately 16 per cent. Powdered basic lead arsenate should contain only 22 to 24 per cent arsenic oxid, and the paste only 10 to 12 per cent. Neither of the latter should have an H in the formula, unless that H is immediately preceded by O, that is, $Pb_4\ Pb\ OH\ (As\ O_4)_3$. The formula is usually written $PbAsO_4$.

The analyses for lead arsenates should be approximately as follows:[1]

[1] Due to possible ranges in percentages of the various ingredients, these sample analyses do not add up to exactly 100 per cent. The analysis on the package should total 100 per cent, however.

Acid Lead Arsenate	*Per Cent Powder*	*Per Cent Paste*
Arsenic oxid (As_2O_5)	31-33	15-16
Water-soluble arsenic, not more than....	.5	.3
Lead oxid	62-64	30-32
Water and impurities, approximately......	3- 5	48-52

Basic Lead Arsenate	*Per Cent Powder*	*Per Cent Paste*
Arsenic oxid (As_2O_5)	22-24	10-12
Water-soluble arsenic, not more than....	.5	.3
Lead oxid (PbO)	72-74	36-37
Water and impurities	5	50

The powdered forms of lead arsenates are the most common on the market. They are finely ground white powders, and are really mixtures of the acid and basic lead arsenates in which the acid lead arsenates predominate. There is wide variation in different brands, both in volume to a given weight and in suspension qualities. R. H. Robinson, of the Oregon Agricultural Experiment Station, in tests made of twelve different brands collected in the open market, found that no relation existed between the dry volume and specific gravity of the different samples (Fig. 5). Those that suspended best in water were found to contain harmless deflocculents or spreaders. Microphotographs of a drop of each of the different samples showed that those containing deflocculents had smaller more uniform particles which tended to form ideal films, while in those without spreaders the particles were grouped in irregular clusters or tended to run unevenly to one side of the drop. The latter, when used as a spray, tended to be washed off easily by rain or heavy dew, while brands containing the deflocculents offered less resistance to rainfall and consequently tended to adhere longer to the surface covered.

Arsenates with larger particles with a spreader were less efficient than those made up of small particles without a spreader. The best test for the grower to make is to place a teaspoonful of each of the several brands of lead arsenate

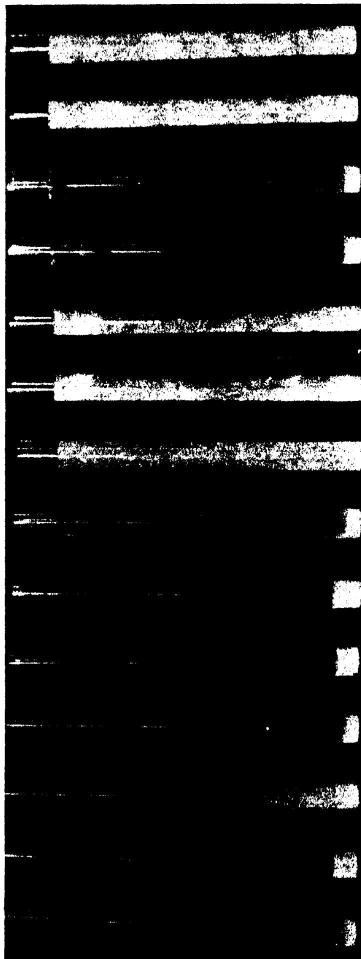


Fig. 5.—Settling tests of different commercial lead arsenates. Brands: 1, Grasselli; 2, Sherwin-Williams; 3, General Chemical Company; 4, Dow; 5, Electro; 6, Devoe and Raynolds; 7, Riches-Piver; 8, Ortho; 9, Rex; 10, Latimer; 11, Corona; 12, Glidden; 13, Corona plus sugar; 14, Glidden plus sugar.

which he has under consideration in quart jars containing water, to shake each thoroughly, and see which brand stays in suspension longest. Other considerations being equal, the one which stays suspended the longest is the best one to use. When thorough spraying is done, it is possible that any commercial brand of lead arsenate having a standard arsenical content, particularly when used with a machine having a powerful agitator, will give satisfactory control of insect pests.

When concentrated lime-sulfur and acid lead arsenate are combined, a greenish-black precipitate is formed which contains lead sulfid and, in small quantities, a soluble salt of arsenic. According to Robinson and Tartar,[1] chemists of the Oregon Agricultural Experiment Station, a considerable reduction in efficiency accompanies this reaction, and to prevent this they recommend the addition of 10 pounds of slaked lime to every 100 gallons of spray water before the lead arsenate is added. R. W. Thatcher and L. R. Streeter,[2] of the New York Agricultural Experiment Station, report this reduction, and state that it can be prevented effectively by adding casein preparations such as calcium caseinate or skim-milk and hydrated lime. What actual effect these chemical changes have in reducing the efficiency of the spray material when used in the field is problematical. However, calcium caseinate, powdered sweet skim-milk, and sweet skim-milk are all relatively inexpensive, and their use is also desirable from the standpoint of increasing the spreading and sticking qualities of the spray. Small quantities of hydrated lime should be used with the skim-milk products.

Whether or not the lime or casein products are added, the spray materials should go in the tank in the following order: water, lime-sulfur, casein or lime (if any), and last of all, the lead arsenate.

[1] Robinson, R. H., and Tartar, H. V., Ore. Agr. Exp. Sta. Rept., 1918-20.

[2] Thatcher, R. W., and Streeter, L. R., N. Y. (Geneva) Agr. Exp. Sta. Bull. 521. 1924.

Lead-arsenate paste can be purchased in either the basic or the acid form. The latter is the most common. It contains approximately 48 per cent water. As spraying recommendations are usually based on powdered acid lead arsenate, approximately twice as much paste must be used as is required of the powdered form. If basic lead-arsenate paste is used, then three times as much as is required of powdered acid lead arsenate must be provided.

The disadvantages of the paste leads are that they are more bulky and troublesome to handle than the powdered forms; the paste and water separate, and it is hard to mix evenly before using them, hence endangering the accuracy of measurements when weighing out portions for the spray-tank; the water dries out of paste lead between sprays, affecting accuracy of dilutions; and there is danger of leakage from the containers and of freezing and bursting of packages in winter.

Some of the precautions in the use of lead arsenates are:

1. Don't attempt to make your own. Buy a good ready-made brand.
2. Don't allow lead arsenate to stand where it may be mistaken for other materials or within reach of animals or near feed-bins. It is a deadly poison.
3. Don't use acid lead arsenate with soap solutions.
4. Don't use acid lead arsenate with very hard water or very alkaline waters. Use basic lead arsenate.
5. Don't let packages containing arsenate of lead paste remain open between sprays. Water evaporates and accurate dilutions are thereafter impossible.
6. Don't use acid lead arsenate with any caustic spray material which does not contain an excess of lime without adding lime equal in weight to the amount of acid lead arsenate, or severe burning may be caused.
7. Don't add acid lead arsenate to the spray solution until all the other materials are in it.

Paris green

Paris green was the first arsenical spray extensively used. Chemically it is the aceto-arsenite of copper, and is made by

pouring together boiling solutions of white arsenic and copper acetate. It is a brilliant green in color. It should contain not less than 54 per cent arsenious acid—almost twice as much as in the standard acid lead arsenates—and not more than 4½ per cent free, or water-soluble, arsenic. This is about eight times as much as is contained in acid lead arsenate, so it is far less safe as a spray. The guaranteed chemical formula on the container should read approximately:

	Per Cent
Arsenious oxid, not less than..........	54
Water-soluble arsenic, not more than..	4.5
Copper oxid	30
Water and impurities..................	12-15

Paris green should be finely divided, especially because of its naturally poor adhesive qualities. Thorough agitation is essential when spraying with it, because it settles rapidly. It is now used principally on truck-crops, especially potatoes, usually in combination with bordeaux mixture. It has retained its place as a spray for truck-crops because the foliage of these plants is less subject to arsenical injury than the foliage of trees, and paris green is cheaper and a more powerful poison than the lead arsenates. It should never be used on tree-fruits, especially stone-fruits, and never in combination with lime-sulfur. The dilutions are as follows:

LIQUID APPLICATION OF PARIS GREEN

Paris green	6 oz.
Stone lime (slaked)[1]...............	2-3 lbs.
Water or bordeaux mixture........	50 gals.

DRY APPLICATION OF PARIS GREEN

Paris green	½ lb.
Lime (slaked) or flour	3 lbs.

For larger or smaller quantities the same proportions should be observed.

Paris green is also used in making poisoned baits, such as

[1] If used in bordeaux mixture the lime is unnecessary.

poisoned bran mash, for controlling cutworms, army-worms, grasshoppers, and similar pests of the field and garden. The paris green is mixed with bran and molasses, 1 pound to 25 pounds of bran for worms, while ½ pound is sufficient if grasshoppers are to be combated. From 1 to 2 quarts of blackstrap molasses and sufficient water to make a thick mash are mixed with the paris green and bran. A tablespoonful of this bait is placed near each plant or about every 2 or 3 feet apart in the row, and preferably toward evening, a day or two before setting out young plants. For grasshoppers, 5 to 10 pounds to the acre is sufficient. Poultry must be kept off the fields while the baits are out. Larrimer [1] advises the use of a small amount of soap on the baits for grasshoppers, stating that it increases the attractiveness to the grasshoppers and improves the mechanical condition of the baits.

Certain warnings should be observed in the use of paris green:

1. Don't use paris green on any tree-fruits.
2. Don't mix paris green with lime-sulfur solution.
3. Don't mix paris green with soap solutions.
4. Don't use paris green without lime unless mixed with bordeaux.
5. Don't allow paris green to stand within reach of live-stock or near feed-bins, or where it can be mistaken for any other material. It is a deadly poison.

Calcium arsenate (arsenate of lime)

Calcium arsenate is one of the newer arsenicals which has come to the front especially because of its use against the cotton boll-weevil. It is a white substance somewhat similar to lead arsenate, the expensive lead having been replaced by the cheaper lime, and it is not only less expensive, pound for pound, than lead arsenate, but has a considerably higher arsenic content, so that less is required in spraying. However, it cannot be used on any stone-fruits, and in many sections

[1] Larrimer, W. H., *Jour. Econ. Ent.*, 14:3, pp. 259-263. 1921.

it has been known to burn apple and pear foliage, so should be applied only with the greatest care. The formula on the container should read:

	Per Cent Powdered Form
Arsenic oxid	40-42
Free or water-soluble arsenic, not more than	.75
Calcium oxid	40-44
Water and impurities	14-16
Carbon dioxid	1- 4

The dilutions for calcium arsenate, according to Quaintance and Siegler, are as follows:

Arsenate of lime powder	¾ lb.
or	
Arsenate of lime paste	2 lbs.
Water or fungicide	50 gals.

Calcium arsenate may be used either with bordeaux mixture or with lime-sulfur. G. E. Sanders, experimenting in Nova Scotia, found that when combined with lime-sulfur for a summer spray it caused less injury to the foliage of apples than lead arsenate and lime-sulfur, and it is employed there to a considerable extent. Investigations in the United States, however, indicate that it is not as safe as lead arsenate on fruit-trees in this country.

Calcium arsenate should be stored in tight metal drums. When stored for many months in veneer barrels or other packages which are not air-tight, enough arsenic may be changed to a water-soluble form to make it unsafe for use as a spray.

Care should be taken on the following points:

1. Don't use calcium arsenate on stone-fruits or on tender foliage or even on apple and pear fruit or foliage, particularly if lead arsenate is easily available.
2. Don't store calcium arsenate in veneer or leaky packages —it deteriorates.

3. Don't allow calcium arsenate to stand within reach of live-stock or near feed-bins, or where it may be mistaken for some other materials. It is a deadly poison.

Other arsenicals

Arsenite of lime, arsenite of zinc, arsenite of lead, white arsenic, sodium arsenate, magnesium arsenate, Scheeles' green, and london purple have been used as stomach poisons for insects, but due to their various compositions and the large amounts of free arsenic contained in them, they have been almost entirely supplanted by safer arsenates for spraying purposes. They are not recommended for any general sprays.

Hellebore

Hellebore is manufactured by grinding the roots of the white hellebore plant to a powder. These roots contain alkaloids powerful enough, both as stomach poisons and contact insecticides, to kill insects, yet harmless to man. Therefore, this poison is highly valued as a spray or dust to combat insect pests on fruit which is about to be harvested. As the material is expensive it is not recommended for general orchard use, but only for special applications on a few plants, such as on currants or gooseberries just before ripening, or on cauliflower just before harvest, and sometimes on cut-flowers. Quaintance and Siegler recommend the following dilutions:

LIQUID APPLICATION		DRY APPLICATION	
Hellebore	1 oz.	Hellebore	1 oz.
Water	1 gal.	Flour or air-slaked lime	5-10 oz.

Other stomach poisons

Sodium fluosilicate has recently been recommended by Marcovitch [1] as a stomach poison for controlling the Mexican bean-beetle, and it is suggested as having possibilities in controlling other insects as well. It is not a new insecticide, according to R. C. Roark, of the United States Department of

[1] Marcovitch, S., Tenn. Agr. Exp. Sta. Bull. 131. 1924.

Agriculture, as it was used as an insecticide as early as 1896 by an Englishman named Higbee. It is a by-product of the manufacture of acid phosphate, is much cheaper than the arsenical sprays, acts as a contact insecticide as well as a stomach poison, kills more rapidly, and is less poisonous to man. The disadvantages are principally that it is difficult to get a "light" or fluffy form for dusting purposes, and that when used as a liquid spray it is more inclined to injure foliage. In the work cited it was applied with nine parts of hydrated lime and caused no injury to bean, potato, and similar foliage.

Barium carbonate is used as a stomach poison, especially in making baits for killing rats and other rodents. The poison is mixed with different types of foods such as ground-meat bait, ground-fruit bait, and cereals bait, and small portions of each are wrapped in papers and scattered in the evening around buildings frequented by rats. The rats carry the papers to their runways, eat the contents, and leave the buildings in search of water, so usually die outside. The poison is used at the rate of one part of barium carbonate to four parts of the bait. Care should be taken that farm animals and poultry do not pick up the baits, those not removed by the rats being collected in the morning. As barium carbonate is very cheap and effective, this is one of the best methods of controlling rats on the farm.

Sodium flourid, calcium flourid, cryolite, calcium fluosilicate, borax, and several other materials have insecticidal value, but have a very limited application at the present time.

CONTACT INSECTICIDES

Nicotine solutions

Tobacco dusts and decoctions have been valued as sprays since earliest days. Nicotine, the native alkaloid of tobacco, is one of the most powerful and quickly acting poisons known, being especially toxic to insects. The particular advantages in nicotine as a contact insecticide are that it may be used on

the most delicate foliage without fear of injury, and it may be combined with other sprays, thus obviating any necessity for extra applications to kill the insects for which nicotine is an essential treatment. It is used particularly for aphis, red-bug, and other sucking insects.

The nicotine is extracted from tobacco stems or refuse and is sold and used at varying strengths. It is possible to make a nicotine spray at home, but considerable difficulty is involved in determining its strength with consequent uncertainty about its effectiveness. Growers will usually find it advisable to buy the commercial nicotine products. The highly concentrated commercial product containing 40 per cent nicotine sulfate is manufactured and widely distributed under various trade names. Less concentrated solutions, if properly diluted, should prove just as satisfactory. The diluted spray material should contain not less than .05 or .06 of one per cent of actual or free nicotine.

The toxicity of nicotine sprays differs with changes in temperature and humidity and hardness of the water, and there is a wide range in the strengths required to kill various insects. Red-bugs, for example, yield readily to solutions as weak as 1 part of 40 per cent nicotine sulfate to 1,200 or 1,500 of water, while aphis are much more resistant to it, requiring about a 1 to 600 or 800 dosage to accomplish results. In warm weather nicotine acts quickly, due to the more rapid evolution of free nicotine which is the toxic agent, and weaker solutions are toxic to the same insects which required strong dosages in the cooler seasons or localities. When used with hard waters, especially those containing magnesium, the toxicity is increased. Volatility of nicotine is increased with alkalinity of the water and toxicity increases with volatility, and basic magnesium compounds seem to act more favorably in this regard than other alkalies. Soft waters are definitely less satisfactory for use with nicotine.

Notwithstanding these factors, no methods have been worked

out by which growers can vary the strength of the solution to fit the exact temperature and humidity conditions of the day when the spray is being applied. Possibly the heavier concentrations recommended by some authorities are calculated to give control under most unfavorable conditions, while the weaker solutions required by others will be satisfactory under average or favorable conditions. At any rate, dilution recommendations do vary more widely than can be explained by the differences in susceptibility of insects and climatic variations. The New York Agricultural Experiment Station recommends 1 part of 40 per cent nicotine sulfate to 800 parts of water, or 1 pint to 100 gallons for general orchard spraying; Quaintance and Siegler, of the United States Department of Agriculture, recommend ¾ pint to 100 gallons or about 1 part to 1,100 parts of water; while the New Jersey Agricultural Experiment Station recommends ¾ pint to 50 gallons or at the rate of 1 part of 40 per cent nicotine sulfate to about 550 parts of water. The zone of safety lies somewhere within these two extremes, probably nearer the stronger solution than the weaker ones, although the high cost of materials tempts the grower to use weaker dilutions.

For small operations, 1 teaspoonful to a gallon should be used or 1 fluid ounce to 8 gallons of soapy water. The insects must be hit to obtain control with tobacco products. Nicotine sprays are generally most effective on hot dry days. To supply a tobacco of exceptionally high nicotine content, which will be grown solely for the purpose of making nicotine products for spraying purposes, D. E. Haley, of the Pennsylvania State College, introduced a new strain of *Nicotiana rustica,* of which over 500 acres were planted during 1926.

Home-made nicotine sprays

While, as stated above, the use of home-boiled nicotine decoctions is not generally advised, if a supply of tobacco stems, sweepings, and refuse is available, these sprays can

be made readily on the farm. Dark types of tobacco are preferred, due to the high nicotine content. According to W. B. Ellett and J. Thomas Grissom,[1] it is economical for the grower to make his own tobacco sprays only where high-grade refuse of such varieties as Narrow-Leaved Orinoco, Medium Smoker, or Cutter tobacco is available on the farm, or can be purchased for not more than $20 a ton. The cost of a satisfactory decoction will then be about 1 cent a gallon exclusive of labor. The only labor involved is that of soaking the refuse in water for twenty-four hours and later transferring the liquid to the spray-tank. It is also claimed that the extracted stems have a fertilizer value of $10 a ton. The following table shows the amounts of tobacco of different grades required to make a .05 to .06 of one per cent solution.

Summary of Field Experiments in Preparing Tobacco Extracts
After Ellett, W. B., and Grissom, J. T., Va. Agr. Exp. Sta. Bull. 208. 1914.

	Kind	*Per Cent Nicotine in Tobacco*	*How Prepared*	*Pounds of Tobacco Taken*	*Gallons of Water Used*	*Volume of Extract Gallons*	*Per Cent Nicotine in Extract*	*Total Per Cent Nicotine Extracted*
1.	Leaves	2.835	Steam Cooker	12½	25	24	.1282	72.44
2.	Stems	.481	Steam Cooker	33	33	29½	.055	85.29
3.	Stems	.609	Open Kettle	30	30	14½	.074	48.46
4.	Stems	.481	Soaked	30	30	23½	.0579	78.00

It is necessary for the grower to know approximately into which grade his tobacco refuse falls in order to use a sufficient quantity to get a decoction of the proper strength. The danger lies in making the solution too weak rather than too strong, as this material will not burn any foliage or fruit. The effects of the spray should be closely watched, and if it is not killing the aphis, red-bugs, or other insects, it should be strengthened.

The customary method of making tobacco decoctions on the farm is by soaking the refuse in water for twenty-four hours

[1] Ellett, W. B., and Grissom, J. T., *Preparation of Nicotine Extracts on the Farm*, Va. Agr. Exp. Sta. Bull. 208. 1914.

and stirring it occasionally, using the full amount of water with which the plants are to be sprayed. Strain off the liquid and it is ready to use, 70 to 80 per cent of the nicotine in the refuse having been extracted.

A quicker method, but somewhat more costly and troublesome than soaking, is by steeping the leaves in hot water, using a steam-boiler or lime-sulfur cooker for the purpose. The refuse is placed in a barrel, vat, or cooker, and the total amount of water to be used in spraying is added. Steam or fire is applied until the boiling point is reached, when it is withdrawn and the decoction allowed to cool, being then ready to use. About the same amount of nicotine is extracted in this way as by soaking in cold water, but the process is accomplished more quickly. Actual boiling should be carefully avoided as the nicotine is very volatile and will be lost rapidly. These decoctions should be made up as they are to be used, as standing for a few days will result in fermentation which may injure the insecticidal properties.

Nicotine dusts

There are two forms of nicotine dust on the market, one made by grinding tobacco refuse to a fine powder, and the other by impregnating some kind of carrier, such as magnesium limestone, with free nicotine or nicotine sulfate. The latter is discussed under "Dusts and Dusting," page 212.

Ground tobacco stems have been utilized against plant-lice about as far back as records of spraying go. The dust made by grinding refuse is still used by both the commercial and home gardener, the former applying it against easily killed sucking insects such as the red-bug, and the latter on low bush plants such as roses, currants, gooseberries, and the like. Inasmuch as the nicotine in ground stems is only slightly volatile, it must be used on hot dry days and in considerable quantities, and for this purpose must be very finely ground. It is claimed by some that ground-tobacco refuse,

when spread on the ground, is of value in combating woolly-aphis on the roots of trees. The rain leaches out the nicotine, carrying it down about the roots of the plant and destroying the insects.

Soaps

These contact sprays were discovered in earliest days, and still remain the popular household remedies for plant-lice. Two important uses of soap at the present time are as a flux in making oil emulsions and as a spreader of nicotine sprays. When used alone as a spray, soap is of value chiefly for combating aphis on house, dooryard, and garden plants. While most spray soaps are made from fish-oil, common laundry soap is also effective when only a few plants in the house or garden are to be sprayed, 1 pound of soap to 2 to 4 gallons of water making a spray strong enough to kill most soft-bodied sucking insects. However, it is not nearly as satisfactory a spray material as nicotine for this purpose.

"Whale-oil soap," or fish-oil soap, is the commonest form of spraying soap on the market. It is usually manufactured by combining fish-oil with water and caustic potash or caustic soda. The potash makes a soft brown soap with a disagreeable fishy odor, called potash-fish-oil soap, while the caustic soda makes a soap of considerably harder consistency, usually requiring slicing and dissolving in hot water when it is to be used. Cottonseed oil may be substituted for fish-oil. The formula, according to Quaintance, and Siegler,[1] should be approximately as follows:

	Per Cent
Fatty matter as anhydrids (fish-oil)......	58
Caustic soda or caustic potash (lye).......	10
Other matter	2
Water, not over..........................	30

The best uses for this soap are as a spreader in nicotine or

[1] Quaintance, A. L., and Siegler, E. H., U. S. Dept. Agr. Farmers' Bull. 908. 1912.

other alkaloid sprays and as a flux in making oil sprays. It should never be used with lime-sulfur solution nor in very hard or, alkaline waters, as these will break down the soap into its original ingredients. Quaintance and Siegler state that fish-oil soaps may also be used with arsenate of lead, bordeaux mixture, and sulfur (not lime-sulfur) solutions to increase sticking and spreading qualities.

Fish-oil sprays should be diluted at the rate of 1 pound to 3 or 4 gallons of water for foliage. Even greater dilutions may be used on more tender plants, or if the insects can be killed easily. Against scale in the dormant season, or as a wash on only the wood of scale-infested house plants in the growing season, it should be used at the rate of 1 pound to 2 gallons of hot water, the application being made before the mixture cools. This is especially true of the soda soaps, which at this dilution will harden and clog the nozzles when cool.

The commercial brands of fish-oil are easy to obtain at reasonable prices and are to be recommended over home-made soaps. Where supplies of fish-oil are easily available, the soaps may be made at home with reasonable ease.

"A good fish-oil soap[1] may be made at ordinary summer temperatures without the aid of external heat according to the formula given below:

Caustic soda	6 lbs.
Water	½ gal.
Fish-oil	3¼ gals.

"Thoroughly dissolve the caustic soda in the required amount of water. Then, while stirring constantly, add the fish-oil very slowly and continue active stirring for about twenty minutes or until the soap is completely dissolved. The home-made fish-oil soaps may be used in about the same proportions as the commercial products."

[1] Van Slyke, L. L., and Urner, F. A., N. Y. (Geneva) Agr. Exp. Sta. Bull. 257. 1904.

Resin fish-oil soap

This material has the advantage over other soap sprays because of its adhesive properties and is used as a sticker in spray materials, especially on cranberries, plums, and grapes. It can be purchased ready mixed, or can be home-made from the following formula taken from Quaintance and Siegler:

Pulverized resin (rosin)	5 lbs.
Concentrated lye	1 lb.
Fish-oil	1 pt.
Water, to make total product........	5 gals.

"Place in a suitable cooking vessel the resin, oil, and one gallon of water, and heat. In the meantime, dissolve the lye in a little hot water and after the resin has softened, carefully pour in the lye solution. Thoroughly stir the mixture and then add four gallons of hot water and boil for about two hours or until the resin soap will unite readily with cold water, making an amber-colored liquid. The total product should be five gallons and any water lost through evaporation should be made up with the necessary amount of additional water.

"Use two to three gallons of the resin-soap 'sticker' to fifty gallons of spray."

Oils

Oil and water alone will not mix. To bring them together a third material, such as soap, calcium caseinate, saponin, or bordeaux mixture, must be used. These materials are called emulsifiers, and when oil and water are mixed by means of an emulsifier the product is called an oil emulsion. It is made up of very minute and separate globules of oil surrounded by a thin film of water. Oil sprays are used chiefly as scalecides and are applied during the dormant season. They will kill the eggs of the European red-mite when applied just before growth starts in the spring, and they will also kill large numbers of aphis eggs, but not sufficient to give complete control, and probably not more than will be killed by concentrated lime-

sulfur. Oils are also effective against leaf-roller in the West and are used to a certain extent as spreaders for other sprays. They have little or no fungicidal value and are in that respect distinctly inferior to lime-sulfur. However, they are pleasant to use and are not corrosive to the spray-pump. They are hard on hoses.

Oil emulsions are made from four types of oils: the highly refined white oils, from which all unsaturated hydrocarbons have been removed; lubricating oils, such as red engine oil; fuel oils, such as kerosene and distillate oil; and crude oils, such as petroleum. Of these, the kerosene emulsion is the oldest and best known, but it has been discarded because of the injuries effected on the trees which have been repeatedly sprayed with it and because of the development of more satisfactory oil emulsions. Distillate and crude-oil emulsions are undesirable for the same reasons. The white oils are doubtless the purest and are freest from acids or any highly volatile compounds that might be injurious. However, they are very expensive, which limits their general use. The lubricating oils appear to be the most desirable of any of the oil sprays, and the best for dormant spraying, according to the Washington State Experiment Station, are those medium lubricating oils which distil about one-half their volume between 240-300° C. at 40 millimeters absolute pressure.

Miscible oils differ from oil emulsions only in regard to the relation of the oil to the emulsifier. Where the latter are water-and-soap solutions of oil, the former are oil solutions of the soap emulsifiers. Emulsions contain about 66 per cent oil, while miscible oils generally contain about 90 per cent oil. Emulsions are murky or milky, while miscible oils are generally clear. Proprietary miscible oils, which have been on the market since about 1905, are usually made from a combination of paraffin and vegetable oils. Some may be less likely to burn plants than the other oil sprays, and some of them are used for summer as well as for dormant sprays. It must be borne in

mind distinctly, however, that oil sprays are generally for dormant use only. They should be employed with greatest caution on stone-fruits even in the dormant season. For example, serious cankering frequently follows the dormant use of oil sprays on peach trees in New Jersey, while in Michigan even pear trees will sometimes be killed during a cold winter following a fall application of a miscible or lubricating oil spray. Dutton [1] has shown that fall applications of oil sprays are probably unsafe. In his work an oil spray broke the rest period in peaches, and killed pear wood, while unsprayed twigs, and twigs sprayed with lime-sulfur remained dormant and uninjured.

Lubricating oils can be prepared for use by either the hot-emulsion or the cold-emulsion method. The hot emulsions are somewhat more stable than the cold emulsions, and can be made up at the beginning of the spraying season and will stand without having any of the oil separate out. Cold emulsions are just as satisfactory if used within a few weeks after they are prepared. If the oil separates out of any emulsion, it can easily be emulsified again by running the material through a pump. The separation of oils from an emulsion can easily be detected by the presence of clear free oil on the top of creamy emulsion. If free oils are present, the material should never be used without first emulsifying it again. Cold emulsions made with calcium caseinate will also emulsify readily with hard water. Due to their great simplicity of manufacture and ability to emulsify with hard water, the cold emulsions are probably the most satisfactory for fruit-growers to make at home.

Cold emulsions

Cold emulsions can be made with either calcium caseinate, bordeaux mixture, or a mixture of ferrous sulfate and lime as emulsifiers. Ramsden and Pickering, two English chemists,

[1] Dutton, W. C., Proc. Amer. Soc. for Hort. Science, p. 177. 1924.

found that the emulsions made with bordeaux mixture were not only prepared more easily than those with soaps but were among the most finely divided and permanent emulsions, having, in addition, a distinct fungicidal value due to the presence of the bordeaux. The late A. M. Burroughs and W. M. Grube, of the Missouri Agricultural Experiment Station, developing the work of Ramsden and Pickering, added the calcium caseinate and saponin emulsions.

The following two formulæ show methods of making the common cold lubricating-oil emulsions, the first without and the second with fungicidal value.

Materials	*Quantities to make 100 gals. of 2% solution ready to spray*	*Quantities to make 100 gals. of a stock emulsion of which 3 gals. in 100 gals. of water would make a 2% oil solution ready to spray*
Formula I		
Lubricating oil	2 gals.	66 gals.
Water	1 gal.	33 gals.
Calcium caseinate (Kayso)	¼ lb.	8 lbs.
Formula II		
Lubricating oil	2 gals.	66 gals.
Water	1 gal.	33 gals.
Copper sulfate (bluestone)	¼ lb. to 8 lbs.	8 lbs.
or		
Iron sulfate (copperas)	¼ lb. to 8 lbs.	8 lbs.
Burned lime	¼ lb. to 8 lbs.	8 lbs.

To prepare Formula I, a solution of calcium caseinate should be made by adding the water very slowly and stirring briskly. This should be mixed with the oil and the whole mixture pumped through a sprayer under pressure into another container. It should then be pumped into a storage container. Usually two pumpings are sufficient. Old hoses should always be used on the sprayer when making emulsions, as oil will rot rubber readily. All emulsions will increase considerably in bulk as they are made, due to the incorporation of particles of

air into the mixture. However, these soon disappear and the emulsion returns to the proper bulk.

To prepare Formula II, the bluestone or copperas should be dissolved in a container holding a small quantity of the water indicated in the formula. This may be done by suspending it overnight in a cloth or burlap sack so that the material just touches the surface of the water. In another container sufficient of the water should be placed to slake the lime. These two solutions are poured into the remaining water as in making bordeaux mixture. Mix this solution with the oil by pumping it back on itself under pressure, using a sprayer and coarse nozzle. After a minute of pumping, reduce the opening in the nozzle to make a fine mist, and pump the emulsion into the spray-tank or into a permanent storage container. This emulsion requires little pumping for complete emulsification. Only freshly made bordeaux or copperas and lime solution should be used in making this emulsion. Stale bordeaux will not emulsify properly.

Hot emulsions

The so-called Government Formula is perhaps the most satisfactory for making the hot lubricating-oil emulsion. It is as follows:

Material	*Amount to make 100 gals. of a 2% spray solution*	*Amount to make 100 gals. of a stock solution*
Lubricating oil ...	2 gals.	64 gals.
Potash fish-oil soap	2 lbs.	64 lbs.
Water	1 gal.	32 gals.

The oil, soap, and water are heated together until the boiling point is reached, when the fire is withdrawn, and while hot the solution is pumped twice through a sprayer under at least sixty pounds pressure and is ready for dilution and use.

Roughly speaking, all of the above formulæ make a stock solution containing 66⅔ per cent oil, as the allowance for the bulk of the emulsifier is so small that it is of little impor-

tance. In diluting for use, 1½ gallons of the stock emulsion added to 100 gallons of water would make a 1 per cent oil spray. If higher percentages of oil are desired in the sprays, multiply 1½ by the percentage of strength desired to get the total volume of emulsion to be used.

The oil emulsion should always be stirred well before measuring out quantities for spraying, as the excess water used in making the emulsion settles to the bottom and the emulsion itself contains more oil at the top than at the bottom.

Fuel oils

Kerosene and distillate are the two most common fuel oils for spraying. Kerosene has been used in pure form in the past to a greater or less extent to spray trees badly infested with scale, making the applications with a very fine mist and only on bright days, but the danger of serious injury to the tree and the development of oil emulsions have made the use of pure kerosene, or even of kerosene emulsion, unnecessary. Distillate emulsion is still used on the Pacific Coast.

Certain distillate oils testing 30° to 34° Baumé are more effective scalecides than kerosene. They are made from the following formulæ:

Distillate oil, raw (30°-34° Baumé)	2 gals.
Fish-oil soap	2-6 lbs.
Water	1 gal.

This material is emulsified in the same way as kerosene emulsion. Certain heavier distillates are also used as mechanical mixtures with caustic soda and water against olive scale. Powerful agitation keeps the oil broken up, but it separates out as soon as the agitation ceases.

Crude oils

The use of crude petroleum is confined entirely to the winter spraying of deciduous trees, being applied only when the

trees are completely dormant. It is used most largely in California for black scale, European fruit-lecanium, European or Italian pear scale, cherry scale, and for some of the other deciduous fruit scales. According to Horne, Essig, and Herms, of the California Experiment Station, it penetrates and kills some of the buds, but the larger part are uninjured and even appear to be stimulated to produce a more vigorous and disease-resistant foliage. In the West, natural crude petroleum testing about 23° Baumé is preferred, although heavier grades can be used if they will emulsify. In the East a grade testing 43° to 45° Baumé is favored, and it is prepared according to exactly the same formula as kerosene emulsion and in the same way. The formula for the Western Crude Oil Emulsion and directions for its preparation are as follows: [1]

Natural crude petroleum (21°-24° Baumé)	25 gals.
Liquid soap (½ the amount for potash-fish-oil soap)	3 gals.
Water, to make	200 gals.

Partly fill the spray-tank with water. Add the liquid soap, agitate thoroughly for a minute, add the crude oil, and continue the agitation while running in the remainder of the water. To kill moss and lichens add 2 pounds of caustic soda. If liquid soap cannot be obtained, use 20 pounds of fish-oil soap dissolved in 10 gallons of boiling water to which 3 pounds of caustic soda or lye have been added for softening. During the spraying operation this emulsion should be thoroughly agitated.

Miscible oils

Miscible oils are on the market under many trade names. They are primarily for dormant use. They should be stirred thoroughly before using. The spray-tank should be free from alkalies and acids. The oils should not be mixed with hard water, and finally, they should be placed in the tank first and

[1] Horne, W. T., Essig, E. O., and Herms, W. B., Calif. Agr. Exp. Sta. Circ. 265. 1923.

the water added to them, slowly at first, and with agitation. Dilutions of commercial solutions vary considerably, 1 gallon being diluted with 10 to 20 gallons of water for dormant use. The grower should always follow the directions on the container when diluting a proprietary oil.

The Washington State College has worked out a simple formula for making a miscible oil at home. The following formula and directions are after Melander, Spuler, and Green:[1]

Material	*Per Cent by Weight*	*Per Cent by Volume*
Lubricating oil	90	91
Cresoap	10	9

"Cresoap, the name here given to the cresylated fish-oil soap emulsifier, is made by dissolving 5 parts by volume of potash-fish-oil soap in 4 parts of cresylic acid, or technical cresol. By weight the proportions are 5½ to 4½. The soap should contain no free alkali and should have 30 per cent of moisture. When the soap is mixed with the cresol the emulsifier becomes fluid and will dissolve at once in the oil. Soda or weak potash soap should not be substituted for the potash-fish-oil soap specified here.

"This is the most concentrated miscible oil, since it contains no inert ingredients. It requires care in being diluted and the first water added must be worked in. Four and one-quarter gallons of the stock are needed to make one hundred gallons of four per cent spray. Where water is very hard, this miscible oil is not advised; a non-soap spray should then be selected."

The manner of diluting miscible oils is of great importance. A miscible oil should never be thrown into a large quantity of water. The water should be added to the oil a little at a time and worked in, until about half a gallon or more of water has been added to each gallon of oil. When this is thoroughly

[1] Melander, A. L., Spuler, A., and Green, E. L., Wash. Agr. Exp. Sta. Bulls. 184, 186. 1924 and 1926.

mixed and a creamy emulsion has been formed, then water can be added more rapidly. When about to fill the spray-tank, it should be emptied and washed out, the required amount of miscible oil poured in, the agitator started, and water run in slowly, allowing the agitator time to whip the water and oil into a creamy emulsion. The remainder of the water can be added as fast as desired. Failure properly to manipulate miscible oils, and even some emulsions, may result in a complete breakdown of the material, and once the oil and water are separated the material is a dead loss. If the amount of oil to be used is so small that the agitator will not dip into it, the oil should be manipulated in a pail before putting it in the tank. Then, if the mixture is transferred to the tank through the suction hose and nozzles, the operation is practically certain of success.

Occasionally batches of home-made and commercial miscible oils will not mix properly with water. Therefore, it is well to experiment with the supplies well in advance of the spraying season. If trouble is experienced with the commercial brands they should be returned. If there is difficulty in diluting the home-made oil sprays, slightly increasing the emulsifier may correct the trouble. Any such correction must be made while the material is in concentrated form. One should never use an oil spray which liberates any free oil when diluted, and never a broken emulsion.

This home-made miscible oil for dormant use is diluted at the rate of 1.1 gallon of stock oil to 100 gallons of water for a 1 per cent solution. In eastern states, usually a 3 per cent solution will control European red-mite, while from 3 to 4 per cent solutions are required to kill scale, but where leaf-roller is present, as in Washington, 8 per cent solutions are recommended. In certain sections 1 per cent solutions are used as summer sprays, but are not generally recommended.

Fatty-acid emulsion (*Cocotine*)

Siegler and Popenoe, of the Bureau of Entomology, United States Department of Agriculture, have developed a fatty-acid emulsion of considerable value as a contact insecticide and which shows promise as an aphicide. The toxic component of this emulsion consists of free or uncombined organic fatty acids, such as caprylic, capric and lauric acids.

Some of these fatty acids may be secured from soap factories. The formula recommended by Siegler and Popenoe for making a stock emulsion follows:

Lubricating oil (Diamond Paraffin).....	110 gals.
Coconut fatty acid (double distilled)..	151 lbs.
Caustic potash (commercial)............	30 lbs.
Kerosene	17 gals.
Water	110 gals.

This stock emulsion is made up by boiling, preferably with steam, and pumping it twice through nozzles under pressure of 60 pounds. It is diluted at the rate of 1 gallon of stock solution to 20 of water.

When the weather is quite cold it may be necessary to heat the drums containing the emulsion, or to use hot water in diluting the emulsion, as the soap does not dissolve readily in very cold water.

Carbolic-acid emulsion

Carbolic-acid emulsion is recommended in California for killing aphis and soft-bodied scale during the growing season. Horne, Essig and Herms, of the California Agricultural Experiment Station, recommend the following:

Fish-oil soap	4 lbs.
Crude carbolic acid	½ gal.
Water	4 gals.

Place the water and soap in a suitable container and boil until the soap is dissolved. Add carbolic acid and continue boiling for twenty minutes. A large vessel should be pro-

vided to prevent boiling over. This stock solution is diluted at the rate of 1 gallon to 20 gallons of water.

Precautions in use of oils

1. Don't use oil sprays for foliage application, particularly deciduous foliage, unless absolutely necessary. They burn.
2. Don't use oil sprays on peaches in dormant season unless absolutely necessary.
3. Don't mix oil sprays and lime-sulfur.
4. Don't rely on oil sprays to control aphis by killing the eggs in the dormant season.

Pyrethrum and buhach

Pyrethrum and buhach are made by grinding the flower-heads and stalks of *Pyrethrum roseum* or *cinerariæfolium*, natives of southeastern Europe. The insecticidal quality lies in a certain very volatile oil which asphyxiates the insect. To conserve this, the material must be kept in air-tight containers. It can be applied to foliage or fruit and the effects will be over within a half hour. Insects should be actually struck for best effect. It is also used in a limited way as both a liquid and a dust on house-plants, as a spray against young cabbage-worms on cabbage or cauliflower which is just about to be harvested, and as a fumigant in rooms or clothes-presses. Pure fresh pyrethrum powder may be diluted with 3 to 10 parts of flour, air-slaked lime, finely sifted ashes, or a similar light material. After mixing, it should stand in an air-tight container for twenty-four hours before use. It is applied by means of a small hand-bellows. When used as a liquid it is diluted at the rate of 1 ounce to a quart of soapy water.

Buhach is a trade name for pyrethrum grown and manufactured in the United States.

Quassia chips

An extract or decoction made from the Jamaica quassia wood yields the active principle quassin which is an effective

aphicide. It kills insects by affecting the nerve cells, and the insects become inactive and die in a state of coma. The tree itself is avoided by insects, so is valued somewhat for woodworking. McIndoo and Sievers, of the United States Bureau of Chemistry, report that soaking 22 pounds of small quassia chips or shavings for twenty-four hours in 100 gallons of water, in which have been dissolved 1.6 pounds of fish-oil soap, will make the most satisfactory quassin spray. The cost, exclusive of labor, will approximate that of a 1 to 800 nicotine sulfate solution, and the solution will be about as satisfactory as an aphicide. However, the trouble involved in making it and the uncertainty of the strength developed make it less practical as a spray.

Concentrated lime-sulfur

This material is the standard scale spray today, being perhaps safer for dormant use than any other material known. It can be employed in almost any dilutions during the dormant season without affecting the plant and repeated applications seem to have no cumulative ill effects on the tree. According to Alvah Peterson, of the New Jersey Agricultural Experiment Station, it is as satisfactory an aphicide as oil sprays when used on apple trees in the delayed dormant season. It is one of the strongest fungicides in addition to having insecticidal value. E. W. Scott and E. H. Siegler, of the United States Department of Agriculture, have shown it to be an effective stomach poison in controlling fall webworm in Michigan, even when used as weak as ½ gallon to 50 gallons of water. Its wide adaptability, availability in both commercial and home-manufactured form, safety, and comparatively cheap cost make it the outstanding dormant spray.

The manufacture of concentrated lime-sulfur has become thoroughly standardized. It is possible to buy it on the market today in fifty-gallon barrels for prices ranging from 12 to 22 cents a gallon, depending on the quantity purchased. In

smaller quantities the price is considerably higher. All commercial brands should test at least 32° Baumé, be a rich amber color, and contain no sludge or heavy material in the bottom of the barrel.

The active principles in concentrated lime-sulfur are the calcium polysulfids. In breaking down into calcium thiosulfate and eventually to calcium sulfate they absorb oxygen, which causes a reduction of the substance from which the oxygen is extracted. Gardeners and fruit-growers occasionally have experienced burning on their hands when using lime-sulfur. This reduction gives lime-sulfur its insecticidal value. Quantities of free sulfur in a very fine state of division are also liberated, giving the material a very high fungicidal value.

In manufacturing concentrated lime-sulfur, approximately two parts of commercial sulfur flour and one part of burned lime are boiled together until the color indicates that the proper polysulfids have been formed. This process has been perfected to a nicety in commercial manufacturing plants, and where there is a factory close at hand so that the freight rates are low, or where only a few barrels are to be used during the summer, the commercial product is usually advisable.

In distant sections where a long haul makes the price of the commercial article prohibitive, or where abundant and pure burned calcium lime is available, or where large quantities of spray are to be used, it may be economical for the grower to manufacture his own lime-sulfur. This is a simple process, especially if steam is available, and even when it is cooked over the open fire the operation is not difficult (Fig. 6). During the past seven years the cost of home-manufactured concentrated lime-sulfur at the author's farm—with sulfur delivered for $2.50 a cwt., lime at 75 cents to $1 a cwt., and labor at 35 cents an hour—has varied between 5½ and 7 cents a gallon for a solution testing about 28° Baumé. The delivered commercial concentrate testing 33° Baumé has cost from 17 to 21 cents a gallon. Taking into consideration the

different densities of the concentrates, the cost of a 200-gallon tank of lime-sulfur, diluted from the commercial concentrate to the proper strength for use during the dormant season, at 20 cents a gallon, is $3.50, while the cost of a 200-gallon tank of the home-boiled concentrate diluted to the same strength, at 7 cents, is $1.49.

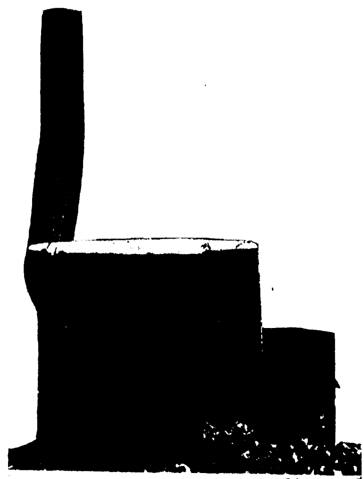


FIG. 6.—Simple type of lime-sulfur cooker. The kettle holds 75 gallons.

There are two ways of making lime-sulfur —by steam boiling or by the open fire. In manufacture with steam, the boiling is accomplished by turning live steam into the barrel containing the ingredients until the proper chemical reactions take place. Several barrels can be boiled at once in this way if the boiler has sufficient capacity. A steam-boiler, some extension outlet pipes, and tight barrels are the equipment needed (Fig. 7). If the open-fire method is used, an iron cooker holding at least 75 or more gallons is preferred. This is suspended over an open fire or mounted on a brick foundation with a fire-box underneath. A scalding vat with a metal skirt or stove makes an excellent cooker.

High-grade quicklime is essential to the manufacture of good concentrated lime-sulfur. A calcium lime at least 95 per cent pure should be used. If there is doubt as to the purity of the lime most agricultural experiment stations will analyze

samples. The presence of more than a few handfuls of sediment in the bottom of the cooker after boiling, or of more than a few inches of sludge in the bottom of the settling barrels, is an indication that the materials are not up to standard, or that the solution is not properly made.

FIG. 7.—Lime-sulfur manufacturing plant in orchard. Six barrels can be made at one time.

Two formulæ are in common use. The best-known is called the 50-100-50 formula:

Burned stone calcium lime (at least 95% pure)	50 lbs.
Commercial ground sulfur flour	100 lbs.
Water	50 gals.

Three or four inches of water are put in the cooker and the fire or steam started. The lime is dumped in and starts slaking. When slaking is well under way, add the sulfur and sufficient water to maintain a thin paste while slaking continues. When slaking is completed add the remainder of the water, putting in a few gallons extra to compensate for the

water lost by evaporation. Stir constantly until the mixture is boiling vigorously, when constant stirring need not be continued. The mixture will tend to boil over, however, and some stirring and the addition of small quantities of cold water will be necessary to check this. Cook for forty-five to sixty minutes, or until all of the greenish-yellow free sulfur has disappeared, and the mixture has become a rich amber color. Strict attention to the boiling period is important because an over-

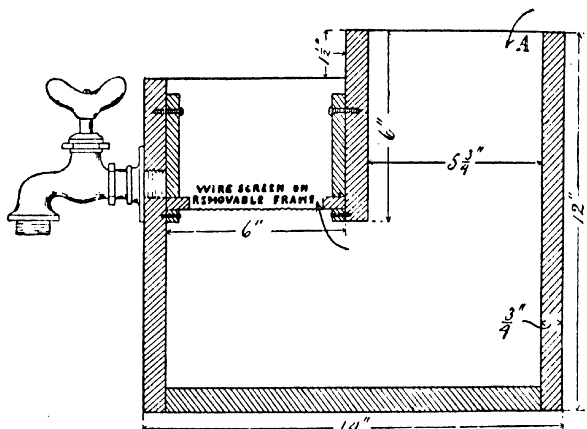


FIG. 8.—Strainer for removing sediment from concentrated lime-sulfur. The material is poured in at A. The sediment settles out and the liquid rises through the wire screen and is drawn off through the faucet.

boiled or an under-boiled solution will have large quantities of sludge. The color is the best indication. Occasionally the right color will be reached by boiling for only thirty-five or forty minutes. When this stage is reached, draw the solution off into settling barrels. After it has stood a day or two, the clear liquid should be decanted off and put into storage bar-

rels and the remaining sludge thrown away (Fig. 8). Place a few drops of lubricating oil on the surface of the lime-sulfur in the storage barrels to protect it from evaporation and from oxidation into less toxic forms by action of the air. It is then ready to use as needed.

In making several barrels at once by the steam method, either sufficient labor must be available to stir the barrels, or else the barrels must be started one at a time until the boiling has commenced in each, when stirring is not as important. The steam from a jet or perforated cap on the end of the steam-pipe, which reaches to the bottom of the barrel, will do considerable agitating in itself. A shaft operating mechanical agitators gives excellent results.

The second formula was developed by the Pennsylvania State College and is as follows:

Lime	45 lbs.
Sulfur	90 lbs.
Water	60 gals.

The advantage in using this formula was that the material cooked more rapidly, there was less sludge, and almost as high concentrations were reached with the finished product. The method of cooking is identical with the 50-100-50 formula. H. C. Young,[1] of the Ohio Agricultural Experiment Station, suggests the use of a formula having 80 pounds of sulfur and 36 pounds of lime, stating that the largest quantity of penta-sulfids are formed when these proportions are used, with a corresponding reduction in the formation of other materials.

The dilution of the home-manufactured concentrated lime-sulfur is important. A Baumé or specific gravity hydrometer for testing lime-sulfur should be secured from a horticultural supply house and the material tested (Fig. 9). Dilutions are then to be made according to the table on page 73.

Concentrated lime-sulfur may be combined with nicotine sulfate, lead arsenate, calcium arsenate, or casein spreaders.

[1] Young, H. C., Ohio Agr. Exp. Sta. Monthly Bull. IX, Nos. 1 and 2, pp. 9-11. 1924.

LIME-SULFUR DILUTION TABLE*

Showing the amount of concentrated lime-sulfur solution of different densities which must be added to water to make 50 gallons of diluted spray

Hydrometer Reading		Winter Strengths										Summer Strengths							
		1 to 8		1 to 9		1 to 10		1 to 15		1 to 20		1 to 30		1 to 40		1 to 50		1 to 75	
Baumé	Sp. Gr.	To Make 50 Gallons of Dilute Spray Use:										To Make 50 Gallons of Dilute Spray Use							
		Gals.	Qts.	Gals.	Qts.	Gals.	Qts.	Gals.	Qts.	Gals.	Qts.	Gals.	Qts.	Gals.	Qts.	Gals.	Qts.	Gals.	Qts.
36	1.330	5	0	4	2	4	0	2	3	2	½	1	2	1	½	0	3½	0	2½
35	1.318	5	½	4	2½	4	½	2	3½	2	1	1	2	1	½	0	3½	0	2½
34	1.306	5	1½	4	3	4	1½	3	0	2	1	1	2	1	1	1	0	0	2½
33	1.295	5	2	5	0	4	2	3	½	2	1½	1	2½	1	1	1	0	0	2½
32	1.283	5	3	5	1	4	3	3	1	2	2	1	2½	1	1	1	0	0	3
31	1.272	6	0	5	2	5	0	3	2	2	2½	1	3	1	1½	1	½	0	3
30	1.261	6	1½	5	3	5	1	3	2½	2	3	1	3½	1	1½	1	½	0	3
29	1.250	6	3	6	1	5	2	3	3	2	3½	2	0	1	2	1	1	0	3
28	1.239	7	0	6	2	5	3½	4	0	3	0	2	½	1	2½	1	1	0	3½
27	1.229	7	1½	6	3	6	1½	4	1	3	1	2	1	1	3	1	1½	0	3½
26	1.218	7	3½	7	0	6	2½	4	2	3	2	2	1½	1	3½	1	1½	1	0
25	1.208	8	1	7	2	6	3½	4	3	3	2½	2	2	1	3½	1	2	1	0
24	1.198	8	3	8	0	7	2	5	0	3	3½	2	2½	2	0	1	2	1	½
23	1.188	9	1	8	2	7	3	5	1½	4	1	2	3	2	½	1	2½	1	½
22	1.179	10	0	9	1	8	1½	5	2½	4	2	3	0	2	1	1	3	1	1
21	1.169	11	0	10	2	8	3½	6	0	4	3	3	1	2	2	1	3½	1	1½
20	1.160	12	0	11	3	9	2	6	2½	5	0	3	2	2	2½	2	0	1	2

1. Test the concentrated lime-sulfur solution with an hydrometer which shows either the Baumé or sp. gr. scale. Locate the figure indicated by hydrometer in the first column on the left.

2. Consult spray calendar to find strength of standard solution to control the pest: *i.e.*, 1 to 8, 1 to 9, etc. Read down that column in the table until opposite the number indicated on hydrometer to find the exact amount of the concentrated solution which must be used to make 50 gallons of diluted spray.

3. Example—Let us assume that a batch of home-made concentrated lime-sulfur tests 27° Baumé (or 1.229 sp. gr.), and that the spray calendar from your state agricultural college advises using standard concentrated lime-sulfur solution at the rate of 1 to 40 to control the pest you are fighting. Locate 27° Baumé or (1.229 sp. gr.) in the first left-hand column, and opposite this figure read across to the right in the seventh column, labelled "1 to 40," where it says "1 gal 3 qts." This quantity of your home-made concentrated lime-sulfur must be used with 48 gallons and 1 quart of water to make 50 gallons of diluted spray equal in strength to a standard 33° Baumé solution diluted 1 to 40. For ordinary purposes measuring to the nearest quart is sufficiently accurate.

*Dilutions calculated from Table XI, N. Y. Agr. Exp. Sta. Bull. 329, 1910, by Van Slyke, Bosworth and Hedges. 33° Baumé (sp. gr. 1.295) was considered the standard density, and the dilutions recommended above will give densities comparable to corresponding dilutions of the standard 33° solution.

Care should be taken to observe the following points in the use of concentrated lime-sulfur:

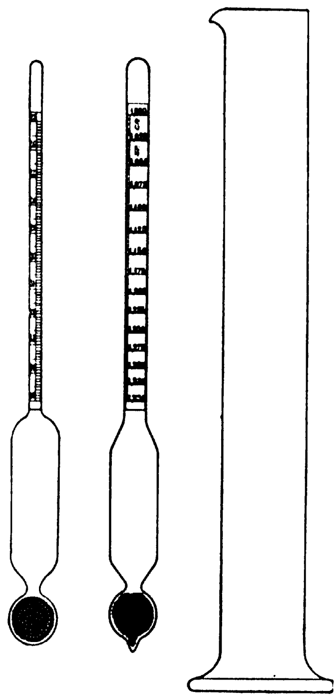


FIG. 9.—Hydrometer equipment for testing concentrated lime-sulfur. Hydrometer on left measures density according to the Baumé scale. Other hydrometer measures according to specific gravity. Cylinder is used as a container when measuring density. Many hydrometers have both Baumé and specific gravity scales.

1. Don't use poor lime in manufacture.
2. Don't combine lime-sulfur with soaps—the latter will be broken down, and the resulting curdled mass will clog the pumps and nozzles.
3. Don't combine lime-sulfur with oil emulsions.
4. Don't use 33° Baumé lime-sulfur stronger than 1 to 40 parts of water during the growing season.
5. Don't combine concentrated lime-sulfur with acid lead arsenate without first adding 10 pounds of slaked stone lime to 100 gallons of the spray solution, or else first diluting the lime-sulfur to the required strength, sifting in 1 pound of casein spreader to 100 gallons, and finally sifting the lead arsenate into the spray.
6. Don't confuse concentrated lime-sulfur with self-boiled lime-sulfur, dry-mix sulfur-lime, atomic sulfur, or dry lime-sulfur.

Soluble sulfur (sodium sulfur)

Soluble sulfur is somewhat similar to concentrated lime-

sulfur except that lye or soda ash is substituted for lime in its preparation. It is used as a dormant scale spray, but has been found unsatisfactory, compared with concentrated lime-sulfur, by Abbott, Culver and Morgan,[1] even when used at far stronger proportions than recommended by the manufacturers, and it has no particular advantages over concentrated lime-sulfur. It cannot be employed in combination with lead arsenate as a foliage spray because it causes severe burning, although it is used somewhat in Canada with calcium arsenate. It is rather more expensive than concentrated lime-sulfur and not as widely distributed and available. Lately it has been utilized as a dust spray when trees are in dormant condition. One of the most promising uses of soluble sulfur is as a fungicide to mix with oil sprays to give them fungicidal value. It is used with oil on citrus fruits quite widely, and to a certain extent on peaches, to control peach leaf-curl.

Barium tetrasulfid (*B. T. S.*)

This material, somewhat similar to lime-sulfur in which the lime has been replaced by barium, has been used by some growers as a substitute for concentrated lime-sulfur. Its one special advantage over the latter is that it is a dry substance, and is hence more convenient to handle and requires less freight. However, it is more expensive to buy, and, like soluble sulfur, it was found unsatisfactory as a scalecide by Abbott, Culver and Morgan.

Dry lime-sulfur

Dry lime-sulfur is obtained by the dehydration of a concentrated lime-sulfur solution containing a stabilizer such as cane-sugar. The outstanding advantage of this material is that it is in powdered form, making possible a considerable saving in freight, and is especially easy to handle in retail or small quantities. It is not as powerful an insecticide at the

[1] Abbott, W. S., Culver, J. J., and Morgan, W. J., U. S. Dept. Agr. Bull. 1371. 1926.

dilutions ordinarily recommended by manufacturers as the concentrated liquid form, and based on the amounts of active ingredients contained it is more expensive at present prices.

According to the Oregon Agricultural Experiment Station,[1] there is apparently a partial decomposition of the polysulfids during the manufacture, because there is more free sulfur and thiosulfate sulfur and less polysulfid sulfur than are found in concentrated lime-sulfur when calculated on a dry basis. Abbott, Culver and Morgan[2] suggest that the reduction in efficiency of dry lime-sulfur is due to the presence of fewer calcium pentasulfids (the most active ingredients), and a larger number of the lower polysulfids than are found in liquid concentrated lime-sulfur. The Oregon Station found further that it would take 4 pounds of dry lime-sulfur having 85 per cent active ingredients to equal 1 gallon of 33° Baumé concentrated lime-sulfur solution in amount of active ingredients contained therein. This indicates that it would be necessary to use far higher amounts of dry lime-sulfur than are recommended by the manufacturers. Were equivalent quantities used, the cost at present quotations would be much above the cost of liquid lime-sulfur. Finally, while there are many cases in which dry lime-sulfur has given satisfactory results, the field experiments carried on by state experiment stations in almost every section of the country have indicated conclusively the need of larger amounts than the manufacturers have recommended in the past, particularly when weather conditions favor the development of serious scale and disease epidemics. Dry lime-sulfur fills a distinct need, however, in furnishing the dooryard gardener a fungicidal spray material in a form convenient to handle. Here the expense is not a great obstacle.

Comparing the cost of a 200-gallon tank of dormant spray

[1] Robinson, R. H., Ore. Agr. Exp. Sta. Bull. 201. 1924.

[2] Abbott, W. S., Culver, J. J., and Morgan, W. J., U. S. Dept. Agr. Bull. 1371. 1926.

solution it would take 17.5 gallons of commercial concentrated lime-sulfur testing 33° Baumé, which would cost $3.50 at 20 cents a gallon. A similar tank of the same strength would take 70 pounds of dry lime-sulfur which, at 9 cents, would cost $6.30.

GASES OR FUMIGANTS

Paradichlorobenzene (P. D. B., paracide, crystal gas)

This material is a crystalline substance having the appearance of Epsom salts. When exposed to air it slowly evaporates, giving off a gas which is five times heavier than air and which is toxic to insects and small animals, but beyond causing headache it has little effect on man. It is used especially for controlling the peach-tree borer on trees two or more years old. It will injure and even kill younger trees unless handled very carefully, so its use on them is not advised. It cannot be employed at all on apple trees without danger of seriously injuring them. E. B. Blakeslee, of the United States Bureau of Entomology, suggested the insecticidal properties of this material, and Alvah Peterson, of the New Jersey Agricultural Experiment Station, developed the method of using it against borers on stone-fruits. T. J. Headlee, of the New Jersey Station, reports that it is also somewhat effective against the larvæ of the oriental fruit-moth, many of which are found around the base of the peach trees.

Paradichlorobenzene should be applied after the eggs of the borers have hatched, and before the soil temperatures are lower than 55° F. In the East, where 99 per cent of the peach-tree borers are usually hatched by the first of September, the material can be applied any time between September 1 and October 15. In the extreme Southeast these dates may be somewhat later. The California Agricultural Experiment Station recommends the application any time from May until November. One-half ounce is sufficient for trees about 4 inches in diameter, ¾ ounce for trees 4 to 6 inches, and 1

ounce for trees over 6 inches. For two-year-old trees 1/4 ounce is sufficient.

The weeds and trash are removed from the base of the tree and the surface, if hard, is broken. If the galleries of the borers are above the surface of the soil as indicated by the gum and castings, the earth should be mounded up around the trunk above the level of these galleries. The paradichlorobenzene should be applied in an even narrow ring about an inch from the trunk, taking care to avoid placing any of the material against the trunk. A few shovelfuls of loose earth should be thrown over it and tamped down with three or four strokes of the shovel. The presence of clods in the covering will allow much gas to escape with consequent lessening of the effectiveness of the application. On two-year-old trees the mound should be drawn away in three or four weeks. Severe injury may result from allowing the material to be around the young trees over winter. The mound should be drawn away from old trees in May or June so that the next crop of eggs can be laid close to the level of the soil, thus doing away with the necessity of further mounding up before applying the material in subsequent seasons.

The material should be kept in tight containers, and should never be stored in the same buildings with fruit, as the fruit will soon taste of paradichlorobenzene.

Carbon bisulfid

Carbon bisulfid or disulfid is a clear liquid which gives off a heavy highly inflammable gas when exposed to the air. This gas is very poisonous to both animals and humans, so should be used with the greatest care. It produces dizziness, nausea, and eventually death. The pure chemical is completely volatile.

This material is a fumigant, being used at the rate of 10 to 20 pounds to 1,000 cubic feet of air space [1] in the room or

[1] Hinds, W. E., U. S. Dept. Agr. Farmers' Bull. 799.

bin. When the room can be tightly closed, thus preventing the escape of the gas, the lower concentrations can be used, but in mills, granaries, storehouses, and buildings where there are cracks or other openings, or when the materials to be fumigated are well wrapped up or inclosed in a husk, the higher charges are necessary. It may be placed in shallow pans or sprinkled directly on the material to be fumigated, but it is essential that the liquid be near the top of the room so that the heavy gas will be completely diffused through all parts of the chamber. The room must be tightly closed to prevent the escape of the gas. Fumigation should continue for twenty-four hours. Temperature must be above 60° F. for it to be effective, and 75° F. is the best temperature. Dwellings, granaries, and warehouses, or small containers, such as cans, may be fumigated effectively in this way.

Carbon bisulfid is also used in destroying ants, grubs and other insects infesting the soils in greenhouses, golf courses, gardens, and other places. For this purpose the material is placed about two inches underground and the holes immediately closed. In greenhouses a couple of holes are bored about four inches from the base of the plant to be protected, and a teaspoonful of carbon bisulfid placed in each and the holes closed. Electric lights should not be lighted or any fire carried near closed buildings when fumigation with this material is in progress, as an explosion is likely to ensue.

Ground-hogs, woodchucks, gophers, squirrels, and other rodents are exterminated by using the pure liquid, by exploding the liquid in the burrows, or by use of a "destructor pump."

By the first method a tablespoonful of carbon bisulfid is poured on a ball of cotton-waste, a corn-cob, horse manure, or other absorptive material and pushed as far into the burrow as possible, the opening being immediately plugged with earth. Some authorities recommend the explosion of the gas with a torch before the hole is plugged. This should be done with

caution where there is danger of fire. The last method is to pump the vapors into the burrow by a specially designed pump called a "destructor," and this method is said to be as effective as the exploding gas.

Hydrocyanic-acid gas

Hydrocyanic-acid gas is the vapor evolved from certain cyanid compounds. It is one of the deadliest poisons. It acts with unusual speed, and must be handled with care to safeguard the health of the operator and other living things.

The most common sources of hydrocyanic-acid gas are calcium and sodium cyanid. When the latter is mixed with sulfuric acid and water in certain proportions the fumes are given off with great rapidity. Potassium cyanid was formerly used, but is more expensive, and has been completely displaced by other forms. Liquid hydrocyanic acid is widely utilized in citrus districts for fumigation of trees to control scale infestations. Calcium cyanid, a new product, has lately come into prominence as a very convenient source of hydrocyanic-acid gas, as it is unnecessary to use sulfuric acid with it, and it is displacing some of the older materials for certain commercial purposes.

Hydrocyanic-acid gas is used for fumigating homes, warehouses, greenhouses, trees and soil and for poisoning rodents and certain kinds of insects. The state of Nevada has substituted it for the gallows and electric chair in criminal executions. Its use is discussed in Chapter XI.

REPELLENTS

Repellents are materials which repel insects through some offensive or unattractive property. Moth-balls are good examples. Tobacco dust, bordeaux mixture, kerosene, whitewash, self-boiled lime-sulfur, dry-mix sulfur-lime, and even common road dust have repellent value. The idea that repel-

lents must have a powerful odor is unsupported by fact, although a number have that property.

Camphor, naphthalene, and carbolic acid are common materials which enter into the manufacture of many of the prepared or proprietary repellents. However, naphtha and carbolic acid are inclined to injure plant tissues, so cannot be widely used except in very small quantities with other substances.

Bordeaux mixture repels the attack of the flea-beetle on potato and tomato plants. Self-boiled lime-sulfur is valuable as a repellent for use against rose-chafers on grapes, roses, and other plants. Concentrated lime-sulfur sludge is employed as a repellent against the attacks of rodents and borers on the trunks of trees. A solution made by using 1 pint of crude carbolic acid to 10 gallons of water, in which 3 or 4 pounds of fish-oil soap have been dissolved, is often painted on the trunks of fruit- and shade-trees in the spring to prevent the attacks of borers and to keep the wingless females of the spring canker-worm from ascending to lay eggs.

Repellents should be applied before, or just as soon as, evidences of insect attack are observed. Substances like tobacco, hellebore, pyrethrum, and buhach, while effective as repellents, soon lose their strength, and therefore can only be used economically just before harvest when protection for only a few hours is desired. When protection is needed over a longer period, more durable coatings, such as bordeaux mixture, self-boiled lime-sulfur or other sulfur sprays, or whitewash, should be applied.

Sticky bands containing substances like "Tanglefoot" form mechanical barriers which are also in a measure repellents. "Ant tapes," which when spread across ant paths will prevent them from crossing, are also of this class.

CHAPTER V

SPRAYING MATERIALS—FUNGICIDES

COPPER and sulfur are the two important elements from which practically every common fungicidal spray is made. The principal combinations are sulfur and lime, ranging from mechanical mixtures of lime and sulfur to intricate chemical compounds, and copper and lime, such as bordeaux mixture, Pickering spray, Burgundy mixture, and many others. Mercury, from which corrosive sublimate is made, formaldehyde, and borax, which is used as an orange dip, are the other materials beside copper and sulfur compounds which are commonly used as fungicides.

There is considerable difference of opinion as to the reason copper and sulfur have these fungicidal properties, and thus far no definite conclusions have been accepted. It is known that copper sprays have a considerably stimulating effect on plant growth, but whether this is due to the changing of the rate of transpiration, the shading of the plant by the film of spray, an electric action set up between the electro-negative copper and electro-positive transpiration current, or direct absorption of copper by the plant, is unknown. All of these theories have been advanced, according to O. Butler,[1] of the New Hampshire Agricultural Experiment Station. Hooker [2] concludes that both the fungicidal and the burning action of copper sprays depends upon the catalytic action of copper in aiding oxidation, pointing out the fact that copper is an oxidizing catalyst that has been found effective in oxidizing

[1] Butler, O., N. H. Agr. Exp. Sta. Tech. Bull. 21. 1922.

[2] Hooker, H. D., Jr., Proc. Amer. Soc. for Hort. Science, pp. 173-176. 1924.

even exceptionally inert compounds. Scientists agree that the fungicidal value of sulfur sprays is due to the presence of free sulfur, but they do not explain why sulfur is toxic to fungous spores. However, it is the result with which the practical gardener and fruit-grower is concerned, and he must accept these two materials as the basis of his most important fungicidal sprays.

COPPER SPRAYS

Home-made bordeaux mixture

Ever since Millardet discovered by accident the fungicidal value of bordeaux in the vineyards of southern France in 1882, it has been the leading fungicide in both Europe and America. It has probably received more attention from scientists than any other spray material, yet the nature of its action still remains a mystery. Various hypotheses have been advanced but none accepted. No one has been able definitely to analyze the fungicidal material. However, it is known that the reaction of copper-sulfate solution and lime-water forms a bulky, adhesive, relatively insoluble precipitate which is the best-known fungicide yet found, being especially effective as a spray for potato-blight, bitter-rot and blotch on apples, and as a general fungicide on tomatoes, melons, and most other vegetable crops.

The fungicidal value of bordeaux mixture, according to C. S. Crandall, of the Illinois Agricultural Experiment Station, is due to the prophylactic action of the contained copper. It has very little curative power nor does it check the growth of fungi within the plant tissues. It does prevent the germination of spores and arrests the growth of germ-tubes, thus checking new or further infection. Therefore the applications of bordeaux mixture, to be effective, must be in advance of the appearance of the fungus. Early application for defense, points out Crandall, is infinitely to be preferred to later applications intended to check the ravages already begun. Exception

to this general rule might be found in the use of bordeaux mixture in controlling certain surface mildews, such as rose mildew, which can be checked relatively easily after infection has taken place.

The method of making bordeaux mixture is of considerable importance. Rightly mixed and freshly made, it is remarkably adhesive and does not yield readily to the washing action of rains. Stale bordeaux is less adhesive than new mixtures. Variations in the preparation and in the proportions of lime and copper sulfate beyond certain well-defined limits also affect adhesiveness. Bordeaux mixture is the one spray which, if used in any considerable quantities, should always be made on the farm, the commercial forms being of less value than the freshly-made products. (See page 89.)

A great variety of formulæ has been presented. All of the earlier ones called for great concentrations and considerable predominance of copper sulfate. New Jersey and Ohio, in 1891, were the first to report the use of the standard 4-4-50 formula (4 pounds of copper sulfate, 4 pounds of stone lime, and 50 gallons of water). Since that date the weaker strengths have been universally adopted, with a tendency to alkalinity secured by using an excess of lime. The common formulæ are now 4-5-50, 4-4-50, and 3-4-50. Grapes are an exception, 5-4-50, 4-4-50, and 4-3-50 being commonly used on them.

Mixing methods for a small acreage are as follows: Dissolve 4 pounds of copper sulfate in 5 gallons of water. In another container slake 5 pounds of stone lime, and when cold strain it into the spray-tank and add water to make 45 gallons. Pour the dilute copper-sulfate solution into the dilute milk-of-lime solution, stirring the mixture vigorously. Never mix the two stock solutions.

For a large acreage a considerable quantity of stock solutions should be prepared. Dissolve 50 pounds of copper sulfate in a 50-gallon barrel by allowing it to hang suspended in a sack so that the bottom of the sack is just below the

surface of the water. In another 50-gallon barrel slake 50 pounds of stone lime, and when slaking is completed fill the barrel to the 50-gallon mark. Thus each gallon of the solu-

FIG. 10.—Well arranged filling station where bordeaux mixture is used. Stock solutions are diluted in the two central barrels on lower platform, and run into the spray-tank through the large pipe and hose extending out from between the barrels. Stock solutions of copper sulfate and lime may be kept in the other barrels on lower platform, or in two large barrels on top platform. Customarily the top barrels hold the water supply.

tion in each barrel holds one pound of lime or one pound of copper sulfate. These two stock solutions will keep indefinitely, especially if a few drops of oil are placed on the surface to

prevent evaporation, or if water lost by evaporation is replaced before measuring out material for spraying. The requisite materials for a tank of spray are then easily measured out, diluted, and mixed as described above for the small operation.

Elevated mixing platforms are common in extensive potato sections (Fig. 10). Such a platform should be provided with an ample water supply and should be sufficiently high so that the solutions will flow by gravity into the spray-tank. A large water-tank holding from several hundred to several thousand gallons should stand well above the platform. Two stock-solution tanks of perhaps one hundred gallons each should stand below the water-tank, being connected with it by large pipes, with faucets to control the water flow. These stock-solution tanks should be far enough apart to permit two 50-gallon dilution barrels to stand between them. The dilution barrels are also connected with the main water-tank by large pipes with faucets. Finally, the dilution barrels should have large outlet pipes from the bottom from which the diluted materials can be run simultaneously through a copper or bronze strainer, sixteen to eighteen meshes to the inch, into the spray-tank which is driven up below.

By this means the bordeaux mixture can be made in large quantities with a minimum amount of trouble. The importance of large connecting pipes should be stressed. Usually a two-inch pipe or hose will fill tanks quickly enough for ordinary purposes. The stock-solution tanks should be large enough to contain material for one full day of spraying. Thus the copper sulfate may be dissolved overnight. One hundred gallons each of the two stock solutions will make 1,250 gallons of diluted 4-4-50 spray. If several machines are running and several thousand gallons are being applied daily, then larger or more tanks must be provided. The main water-tank should hold enough to supply water for several days of spraying. An outlet directly from the water-tank to the spray machines is desirable to facilitate washing out the machines, drawing water for the spray engines, and other purposes.

A third simple method for making bordeaux mixture, when the platform is not available, is as follows: Fill the sprayer three-fourths full of water. Dilute the stock copper sulfate and lime solution with the remaining quarter of the water. Strain the milk-of-lime solution in the tank first, and then add the copper-sulfate solution with the agitator running.

Bordeaux mixture should be applied immediately after it is made. Standing reduces its effectiveness and adhesiveness. If a sprayer must stand for several hours, adding a heaping tablespoonful of ordinary table-sugar dissolved in a little water to every 100 gallons will preserve the spray indefinitely.

Bordeaux mixture will attack iron and steel. One should always use brass, bronze, or porcelain-lined pumps, and brass or bronze spray-rods, nozzles, and strainers. All spraying equipment should be cleaned after use.

Bordeaux mixture may be tested for the presence of free copper sulfate by two methods. One is to hold a polished knife blade in the solution for a moment. If no copper is deposited on it the mixture is safe. The other method is by allowing a drop of potassium ferrocyanid to fall in the mixture. If the drop remains yellow the mixture is safe, but if a brownish precipitate is formed more lime must be added to the solution until additional drops of potassium ferrocyanid remain yellow in color.

Bordeaux mixture may be combined safely with lead arsenate, calcium arsenate, paris green, oil emulsions (bordeaux mixture giving fungicidal value to the oil sprays), nicotine sulfate, lime-sulfur, and fish-oil soaps.

Burned stone lime is generally the best material to use in bordeaux mixture. There are very finely ground hydrated limes on the market now that will do quite as well as stone lime, but they are usually more expensive. In using hydrated lime for stock solutions, 66 pounds must be utilized instead of 50 pounds of stone lime in a 50-gallon barrel of stock solution.

Bordeaux mixture should be handled carefully, as follows:

1. Don't be careless in weighing and preparing materials.
2. Don't mix the stock solutions. Always dilute them first.
3. Don't use hydrated lime at same rate as burned lime. Bordeaux requires 33 per cent more of the hydrated lime than the stone lime.
4. Don't allow bordeaux mixture to stand before using. If delays are unavoidable add a heaping tablespoonful of table-sugar to each 100 gallons of bordeaux mixture.
5. Don't use bordeaux mixture with iron or steel equipment. Pumps and accessories should be made of brass or bronze or be porcelain lined.

Commercial bordeaux mixture

Commercially prepared bordeaux mixtures are on the market under various proprietary names and for widely varying prices. Many of these preparations are of considerable fungicidal value; others are not. The best bordeaux mixture is fresh, having greater effectiveness and better adhesiveness. The commercial products are generally less effective, having less adhesiveness, and, due to far less quantities of copper than are in the home-made solutions, they are not as satisfactory.

The home gardener or grower who wishes only a few gallons of spray needs an already-prepared product. Doubtless a well-prepared proprietary compound is better than a poor home-prepared mixture. Undoubtedly spraying with a weak mixture is better than none at all, and in many cases in which fungous outbreaks are of a mild nature, the weak proprietary compounds will be satisfactory. But when diseases are prevalent and severe, the general run of commercial preparations are not to be relied on as firmly as fresh properly prepared bordeaux mixture.

The grower should ascertain two major points before he relies on a commercially prepared bordeaux mixture. First, what is the copper-sulfate content in 50 gallons? Second, will the material stay in suspension well?

First, a home-made 4-4-50 solution will have 4 pounds of copper sulfate in 50 gallons of spray. The manufacturer of

commercial bordeaux is required by law to put the analysis of the mixture on the container, in such a statement as this:

		Per Cent
Active ingredient	Copper	2.41
Inert ingredient	Lime	97.59

If the active ingredient is given as "copper" or "metallic copper," the percentage should be multiplied by 3.93 to get the percentage of copper sulfate.[1] If it is stated as copper oxid (CuO), multiply by 3.14 to get the percentage of copper sulfate. If it is given as copper hydroxid [$Cu(OH)_2$], multiply by 2.56. Knowing thus the equivalent of copper sulfate in each pound of the commercial preparation, the amount in 50 gallons of diluted solution may be calculated by multiplying this percentage obtained by the number of pounds recommended on the package for 50 gallons of spray. Home-made bordeaux mixtures have from 3 to 5 pounds of copper sulfate to 50 gallons. To be as effective the commercial solution should approximate this amount, or sufficient quantities used to make up for the difference.

Bordeaux Formulas Corresponding to the Strength of Bordeaux Mixtures Produced When Commercial Preparations Are Diluted as Directed.

Metallic copper declared on label.	Approximate formula of bordeaux mixture produced where the dilution is at the rate of 1 pound to—			
	10 gallons	8 gallons	5 gallons	3 gallons
1.5 per cent	0.3-0.3-50	0.4-0.4-50	0.6-0.6-50	1.0-1.0-50
2 per cent	.4- .4-50	.5- .5-50	.8- .8-50	1.3-1.3-50
2.5 per cent	.5- .5-50	.6- .6-50	1.0-1.0-50	1.6-1.6-50
3 per cent	.6- .6-50	.7- .7-50	1.2-1.2-50	2.0-2.0-50
3.5 per cent	.7- .7-50	.9- .9-50	1.4-1.4-50	2.3-2.3-50
4 per cent	.8- .8-50	1.0-1.0-50	1.6-1.6-50	2.6-2.6-50
4.5 per cent	.9- .9-50	1.1-1.1-50	1.8-1.8-50	2.9-2.9-50
5 per cent	1.0-1.0-50	1.2-1.2-50	1.9-1.9-50	3.3-3.3-50
6 per cent	1.2-1.2-50	1.5-1.5-50	2.3-2.3-50	3.9-3.9-50
7 per cent	1.4-1.4-50	1.7-1.7-50	2.7-2.7-50	4.6-4.6-50
8 per cent	1.6-1.6-50	2.0-2.0-50	3.1-3.1-50	5.2-5.2-50
9 per cent	1.8-1.8-50	2.2-2.2-50	3.5-3.5-50	6.0-6.0-50
10 per cent	2.0-2.0-50	2.4-2.4-50	3.9-3.9-50	6.5-6.5-50
11 per cent	2.2-2.2-50	2.7-2.7-50	4.3-4.3-50	7.2-7.2-50
12 per cent	2.3-2.3-50	2.9-2.9-50	4.7-4.7-50	7.8-7.8-50

[1] Wallace, E., and Evans, L. H., U. S. Dept. Agr. Farmers' Bull. 994. 1918.

Second, the gardener should know whether the material will stay in suspension well. A half teaspoonful shaken well in a quart of water will determine this. If most of the material settles to the bottom in five or six minutes, then the mixture is likely to prove unsatisfactory. A well-made fresh solution will stay in suspension for half an hour. Good agitation is essential in applying commercial bordeaux mixtures.

Bordo-lead-arsenate mixtures, so called because they contain arsenical insecticides, ready to apply to control both insects and diseases, are also on the market. The grower must examine the label for the amount of arsenic, which will be given as total dry or total paste arsenic and total water-soluble arsenic. *The latter should never be more than ½ of 1 per cent.* The standard recommendations for using powdered lead arsenate, containing 30 to 34 per cent total arsenic oxid, are at the rate of 1 to 1½ pounds in 50 gallons, while with paste forms, containing 14 to 17 per cent total arsenic oxid, 2 to 3 pounds in 50 gallons are used. The grower can easily compare the amounts of arsenic oxid in 50 gallons of diluted spray.

There are the so-called "two-powder" forms of commercial bordeaux mixtures on the market which, if combined according to directions, will give excellent results. The Oregon Agricultural Experiment Station believes that these should be used in preference to paste forms if it is not feasible to prepare the home-made article.

Pickering spray

This is a variation of bordeaux mixture in which only a small proportion of the copper is used, and in which the lime is handled in a little different way. In several states it has been found equal to bordeaux mixture as a fungicide, and the cost is much less. Like bordeaux mixture, it cannot be used on tender foliage.

The stock solution of copper sulfate is made as with bordeaux mixture. A saturated solution of lime-water is made by

slaking 4 pounds of stone lime in 100 gallons of water and stirring six or eight times, allowing the insoluble particles to settle after each agitation. The lime-water is then settled, and only the clear solution is used in making Pickering spray. Place $93\frac{3}{4}$ gallons of clear saturated lime-water in the spray-tank. Add 23.1 quarts of stock copper-sulfate solution and stir for one minute. Add water to make 100 gallons.

Burgundy mixture

This spray leaves no residue or stain on ripening fruit or foliage, so can be used as a substitute for bordeaux mixture on small-fruits and such other plants as will not be burned by that spray. The formula is:

Copper sulfate	1	lb.
Sodium carbonate (sal. soda)......	$1\frac{1}{2}$	lbs.
Water	50	gals.

The procedure is exactly as in making bordeaux mixture. Stock solutions may be prepared where the materials are to be used in quantities.

Copper carbonate

Copper carbonate dust is used extensively in the West for treating seed wheat for bunt. Two ounces of copper carbonate should contain 50 per cent of its copper in the form of carbonate and hydrate of copper, and must be very finely ground. The California Agricultural Experiment Station advises that it be sufficiently fine so that it will weigh 32 pounds to a cubic foot.

Copper sulfate (bluestone)

This material, which is employed so widely in the preparation of copper sprays, until recently was used as a grain dip for controlling bunt, smut, and other diseases. Since the advent of copper carbonate dust, formaldehyde, and organic mercury compounds the use of bluestone is not advised.

Other copper sprays

Ammoniacal copper carbonate is a spray made of copper carbonate and ammonia which leaves no stain or sediment on the fruit or foliage. It is more likely to cause burning and is less effective as a fungicide than bordeaux mixture. Burgundy mixture is to be preferred.

Soda bordeaux is another non-staining copper spray made of copper sulfate and caustic soda, but has no advantages over Burgundy mixture.

SULFUR SPRAYS

Wettable sulfurs

Sulfur alone is a powerful fungicide and is becoming more widely used, especially as a dust or as a summer spray to replace concentrated lime-sulfur, bordeaux mixture, and other more caustic solutions which cause burning under certain conditions. However, sulfur alone is difficult to wet with water, so a number of substances, such as calcium caseinate, oleic acid, glue, diatomaceous earth, flour, and dextrin have been used as fluxes. Commercial wettable sulfur pastes, containing 45 to 50 per cent or more sulfur and the remainder water, and a substance like those named above, are on the market. An example of these is atomic sulfur. The effect of these pastes is like that of dry sulfur. When used in sufficient quantities they are efficacious. The dilutions recommended on the packages, however, frequently do not give great enough concentration of sulfur and the materials may not be satisfactory for that reason. Based on the analysis given on the package, sufficient material should be used to put from 6 to 8 pounds of actual sulfur in every 50 gallons of diluted spray. Caution must be observed when mixing these sprays with arsenicals. Lime must be added when arsenicals are used. Just what function the lime has, aside from neutralizing any free arsenic in the poison is not clear, but it is active in preventing sulfur burning which often happens when arsenicals are added to sulfur sprays.

The usual procedure is to add 2 to 4 pounds of lime for each pound of arsenical.

Very thorough spraying is essential when using sulfur pastes, as the material is not as powerful a fungicide as concentrated lime-sulfur or bordeaux mixture. Agitation must also be vigorous, as most of these materials settle rapidly.

Sulfur-lime-glue and sulfur-lime-calcium-caseinate mixtures are wettable sulfurs. The former have been in use since about 1915, while the latter have sprung into prominence since 1922. Previous to that time self-boiled lime-sulfur had been relied on as a mild fungicide for delicate foliage and fruit, but as this material was troublesome to make a simpler mixture was sought. The sulfur-lime-glue mixture came first. This material was still unsatisfactory as it required hot water for dissolving the glue. So the sulfur-lime-calcium-caseinate mixtures, which can be prepared dry at any time and sifted into the tank as needed, have become popular.

The usual formula for making sulfur-lime-glue is:

Commercial sulfur flour	8 lbs.
Hydrated lime	4 lbs.
Increase the lime content to 8 lbs. when this material is to be used with lead arsenate.	
Powdered glue	½ oz.
Hot water	1 gal.
Water, to make	50 gals.

The glue is dissolved in the hot water and this glue water is slowly added to the sulfur, making a thin paste free from lumps. This is washed through a 16- to 20-mesh screen into the spray-tank and the remaining water added to make 50 gallons. This process can be hastened by having a stock glue solution made by dissolving 1½ pounds of glue in 50 gallons of water. Then hot water is unnecessary at the mixing station.

The formula for dry-mix sulfur-lime was developed by A. J. Farley, of the New Jersey Agricultural Experiment Station.

Calcium caseinate is substituted for glue in the above mixture and the ingredients can be mixed at any time during the winter and stored in bags containing just sufficient material for one tank for spray, and inasmuch as 50 pounds of the material are required for a 200-gallon tank of spray, the bags are of a convenient size to be handled in home manufacture and commercial distribution.

Dry-mix sulfur-lime should not be confused with dry lime-sulfur. The latter contains the dehydrated polysulfids of calcium, while dry-mix sulfur-lime is merely a mechanical mixture of sulfur, hydrated lime, and either calcium caseinate, powdered skim-milk, or a similar material. The formula as usually printed is as follows:

Sulfur (commercial flour, or dusting)....	8 lbs.
Hydrated lime (finely ground finishing)..	4 lbs.
Calcium caseinate	½ lb.
or	
Powdered skim-milk	½ lb.
Water	50 gals.

Further tests of the material have shown that there is too little lime in this formula to allow the dry-mix to be used with lead arsenate without danger of burning of foliage, particularly the leaves and new shoots of the peach. Therefore 8 pounds of hydrated lime are recommended whenever arsenicals are to be combined with this spray.

The ingredients are mixed dry in a tub or barrel, and then sifted into the spray-tank which is a quarter or a half filled with water, having the agitator running. Another method is slowly to wash the dry material through the screen by the force of the water with which the tank is being filled. A third method is to add water to the ingredients after they have been mixed dry until a thin paste has been made. This is poured through the screen into the tank. The second is the most popular method where a gravity flow of water is available. Thorough agitation is necessary when using this spray.

Dry-mix sulfur-lime is a substitute for self-boiled lime-sulfur. It is of special value as a summer spray on peaches, plums, and cherries, and for those varieties of apples that are especially susceptible to spray burning with concentrated lime-sulfur. It is to be used from petal-fall on through the summer. It is not strong enough to be relied on for the control of scab in the pre-pink and pink-bud applications on apples in wet seasons, but very little burning is experienced when concentrated lime-sulfur is used at that time. Jonathan, Duchess, Williams Early Red, Grimes Golden, Ben Davis, and Gano are some of the varieties which are burned easily by concentrated lime-sulfur in the summer.

Lead arsenate and nicotine sulfate may be added to dry-mix sulfur-lime. Dry-mix should not be used with oil sprays or soaps.

The following precautions should be observed with wettable sulfurs:

1. Don't rely on wettable sulfurs for the control of apple- and pear-scab in pre-pink and pink-bud sprays.
2. Don't use lumpy or low-grade hydrated lime.
3. Don't use any lime-sulfur sprays without first straining them. Sprayer trouble is thus avoided.
4. Don't combine lime-sulfur sprays with soaps.
5. Don't let self-boiled lime-sulfur burn during manufacture. Always add the full volume of water when the brisk boiling subsides.

Self-boiled lime-sulfur

Self-boiled lime-sulfur has been used in the eastern half of the United States as a summer spray for stone-fruits and as a substitute for concentrated lime-sulfur on such apples as are easily burned by that material from the petal-fall spray on through the summer. While it is mainly a mechanical mixture of sulfur and lime, the heat generated by the slaking lime causes some chemical reaction and the formation of some mildly caustic calcium and sulfur compounds, and also tends

further to disintegrate the sulfur particles, giving a mixture of milk of lime containing very finely divided sulfur in suspension. The formula is as follows:

Sulfur (commercial flour)	8 lbs.
Stone lime (burned lime)	8 lbs.
Water	50 gals.

The burned lime is placed in a barrel and sufficient water added to start slaking. If a poor grade of stone lime is used it may be necessary to employ hot water to start slaking. When slaking is well started, the sulfur is dumped in and the mixture vigorously stirred, sufficient water being added from time to time to maintain the slaking and to keep the mixture from burning. When the vigorous boiling ceases, add the remainder of the water. Do not let the mixture boil long enough to cause the formation of amber-colored streaks on the surface. These are the calcium polysulfids and are likely to burn tender foliage. Always cool the mixture by adding the total volume of water as soon as vigorous boiling has ceased. Thorough agitation is essential when applying the spray.

Potassium sulfid (liver of sulfur)

This is a sulfur spray used on ripening fruit, such as currants and gooseberries, when a stainless spray is needed. It is not as effective as bordeaux, for which it is a substitute, in the general control of fungous pests, but it is very efficient against powdery-mildew, and is also claimed to be toxic against fruit-worms and even caterpillars protected by silken webs. The web is decomposed by the spray which penetrates the body, liberating hydrogen sulfid, thus killing the insect. The formula is as follows:

Potassium sulfid	1 lb.
Water	50 gals.

The potassium sulfid is dissolved in a convenient amount of water and diluted to make the fifty gallons. Spray with it

immediately, as it loses strength upon standing. Keep the potassium sulfid in a tight container. Do not use potassium sulfid on stone-fruit foliage. It burns.

Other uses of sulfur

Sulfur alone is widely used as a dust spray for orchards, vineyards, and gardens for the control of fungous diseases. This is fully discussed in the section entitled "Dusts and Dusting."

Sulfur is also smeared or dusted on steam-pipes in greenhouses, the vapors given off having a fungicidal value especially in controlling mildews.

Sulfur is used as a fumigant for dwellings, sticks being burned in rooms to control clothes-moths and other household pests.

THE REMOVAL OF SPRAY RESIDUES

The removal of spray residues has become a serious problem in sections in which heavy spraying with arsenicals is required for the control of such pests as codlin-moth or celery leaf-tyer. The presence of these residues has caused the seizure and condemnation of many carloads of fruit and vegetables, particularly since 1920, entailing severe losses to growers. Indirect losses of greater importance are also suffered through the disturbance of the public mind. In 1925 the unfounded rumor of the death of a child from eating arsenic-sprayed peaches from a certain section of New Jersey ruined the New York market for peaches from that state for three to four days during the height of the Elberta season. In 1926 the arrest and conviction of certain fruit-dealers in England for selling American-grown apples with more than the tolerance of arsenic caused sharp declines in the export trade for the remainder of the season.

Authentic cases of sickness from eating arsenic-sprayed fruit are difficult to find, and it is safe to say that they are

rare indeed. A medicinal dose of arsenous oxid is from 2 to 5 milligrams. A dangerous dose is about 60 milligrams, while the minimum fatal dose recorded, according to O'Kane, Hadley, and Osgood,[1] is 130 milligrams. The tolerance allowed in the United States for the season of 1927 is 2½ one-hundredths (.025) of a grain of arsenous oxid a pound, and for the 1928 season and thenceforth it will be one-one-hundredth (.01) of a grain a pound. The standard in Great Britain is one-one-hundredth (.01) of a grain a pound, so after the 1927 season the two tolerances will agree. Tests made by the Federal Bureau of Chemistry have shown many cases in which the amounts of arsenous oxid on fruit are above the tolerances, reaching as high as 6 or 7 hundredths of a grain to a pound in extreme cases. Even then it would appear that the quantity of arsenous oxid swallowed while eating even large amounts of fruit is small, compared with a medicinal dose. It is believed by physiologists, however, that amounts less than a medicinal dose would be injurious to health, and the Bureau of Chemistry has taken a firm position in requiring a reduction of arsenic on fruits and vegetables.

The removal of these residues has become an essential operation in preparing fruit for market. Until 1926 the wiping of the fruit with cloth gloves or by mechanical brushes was considered effective. This apparently removed the sprays and little attention was paid to the fruit by the health authorities if the deposits were not plainly visible. Since the recent agitation chemical analyses have shown that wiping will not remove sufficient spray in many cases, and further treatment is necessary. Extensive experimental work is being done to find poisons which will be non-toxic to humans, and to develop methods of removing arsenic from fruits and vegetables. The problem is new, and marked improvements will doubtless be made in methods in 1928 and 1929.

[1] O'Kane, W. C., Hadley, C. H., Jr., and Osgood, W. A., *Arsenical Residues After Spraying*, N. H. Agr. Exp. Sta. Bull. 183. 1917.

Dilute hydrochloric (muriatic) acid has been found by Robinson and Hartman [1] to be effective in removing residues not only of arsenate of lead, but of lime, copper and lead as well from apples and pears. This solution is non-injurious to the fruit, relatively inexpensive, and easily available. These workers found in their experiments that the mechanical methods tried by them did not remove sufficient residues, particularly in the stem and blossom cavities, caused some bruising and stem-puncturing, and in all cases the wiped apples showed more visible wilt and had poorer storage quality than untreated or acid-treated fruit.

The treatment suggested by Robinson and Hartman is to immerse the fruit in a tank of agitated dilute hydrochloric acid, or to spray the acid solution on to the fruit with force. After sufficient treatment the apples are thoroughly washed with fresh water and allowed to dry somewhat before being packed. Complete drying is advisable if possible. The table on page 100 shows the strengths of solution, temperatures of the bath, and length of time of immersion of the fruit which can be used safely for apples and pears.

The experiments cited here indicated that the visible residue is removed in the first ten to twenty seconds, and that 90 per cent of the residue is removed in the first half-minute, and only 5 per cent more is removed by increasing the time of immersion to ten minutes. Agitation of the acid solution was important, as it helped to break up the residues by physical means, and to remove the substance from the surface of the fruit.

Only slight amounts of hydrochloric acid react with the spray residues, and the bath may be used repeatedly. Certain amounts of the solution are carried away by the treated fruit, and the replacement of this loss with fresh acid and water of the original proportions, together with the occasional change

[1] Robinson, R. H., and Hartman, H., *Progress Report on Removal of Spray Residues from Apples and Pears,* Ore. Agr. Exp. Sta. Bull. 226. 1927.

AMOUNTS OF HYDROCHLORIC ACID THAT MAY BE USED WITH SAFETY AT VARIOUS TEMPERATURES AND FOR VARIOUS PERIODS OF TIME.
From Ore. Agr. Exp. Sta. Bull. 226. 1927.

Length of immersion, minutes	*Temperature of solution in °F.*	*Acid-concentration, approx. %*	*Gals. of commercial hydrochloric acid per 100 gallons of water*
10	95	.27	.9
10	72	.33	1.0
10	50	.37	1.1
10	35	.40	1.2
5	95	.97	2.9
5	72	1.0	3.0
5	50	1.0	3.1
5	35	1.1	3.2
1	95	2.3	6.9
1	72	2.3	7.0
1	50	2.3	7.1
1	35	2.4	7.2
1/2	95	2.6	7.9
1/2	72	2.6	8.0
1/2	50	2.7	8.1
1/2	35	2.7	8.2
1/4	95	2.8	8.9
1/4	72	3.0	9.0
1/4	50	3.0	9.1
1/4	35	3.1	9.2

of solution to remove the dirt and debris which accumulates, is sufficient to maintain the strength of the solution for practical purposes.

Commercial hydrochloric acid, usually called muriatic acid, can be secured from any dealer in heavy chemicals. It comes in standard sized twelve-gallon carboys. The labels should guarantee a density of 20° Baumé, which indicates about 32 per cent actual acid in the material. With this stock solution approximately 3 gallons in 100 gallons of water will make a 1 per cent solution.

There are two grades of acid on the market, the commercial, described above, and an expensive chemically pure grade. The commercial grade is a brownish color, due to impurities, while the pure grade is clear. The cheaper grade is entirely satisfactory for washing purposes. According to Shear, of the

Poughkeepsie New York Branch Experiment Station, 900 barrels of apples were treated in 1926 at a cost of 30 cents for acid.

Manufacturers of grading and packing equipment have perfected washing machines which are satisfactory for removing spray residues. Some of these wash by immersion, while others spray the fruit with the cleaning solution. Some of these machines have drying equipment attached, so that the fruit can be packed immediately after washing. When drying equipment is not installed the fruit should stand in crates until the excess moisture is dried from the stem and blossom ends.

For small quantities of fruit washing can be done in a hogshead or trough, small quantities being put in at a time. Growers who are not using grading equipment, and who handle all their fruit by hand will need to work out methods of their own for washing the stained fruit conveniently.

In buying or making washing equipment the use of metals which will be corroded by hydrochloric acid should be avoided. The use of hard rubber and porcelain has been adopted by some manufacturers for pump equipment with which to pump the acid spray through the nozzles in the washer. Iron and steel are soon eaten away.

MISCELLANEOUS FUNGICIDES

Hydrated lime

Lime has long been used as a spray material, principally as a repellent to keep insects off dooryard vegetable and berry crops, and as a carrier for sulfur, arsenic and copper in dusts, a filler, and a marker. It is usually included in liquid sprays to reduce the caustic properties of sulfur and lime, and to neutralize such free acids that may be formed when arsenicals are mixed with these materials.

Ballou and Lewis [1] report that high-grade fresh hydrated

[1] Ballou, F. H., and Lewis, I. P., Ohio State Hort. Soc. Proc. Feb., 1926.

lime alone has given excellent results as a fungicide when used in southeastern Ohio for controlling apple-scab and apple-blotch. For three years ending in 1925 lime had given commercial control, the results in 1925 with lime and casein showing 84, 90, and 96 per cent scab-free fruit on old Rome, young Rome trees, and Ensee trees respectively, while unsprayed Rome trees carried only 2.5 per cent scab-free fruit. They point out that perhaps some of the high fungicidal value hitherto attributed to sulfur and copper may be due partially to lime, but that further experimental work is essential before growers will be justified in turning to lime as a fungicide.

Formaldehyde

This material, as both a liquid and a gas, has been widely used as a disinfectant since 1888. Its toxicity is due to its reducing power; that is, it takes oxygen from the matter with which it comes in contact. The liquid form is merely the solution of the gas in water and is frequently sold under the name of formalin. It is supposed to be a 40 per cent solution, but it occasionally runs as low as 32 per cent.

The principal use of formaldehyde (formalin) has been in the disinfection of seed-beds, seed grains, and seed potatoes. For oat-seed treatment equal parts of formalin and water are used at the rate of 1 quart to 50 bushels of seed. For dipping potatoes, 1 pint to 30 gallons of water is used. For disinfecting seed-beds in greenhouses, coldframes, or hotbeds, 3 pints are diluted with 50 gallons of water, and 1 gallon to a square foot is applied, the soil being kept covered with canvas, old rugs, or burlap a day after soaking and allowed to stand a week thereafter before planting. At first the plants are stunted slightly, but they soon recover and grow with increased vigor.

Mercuric bichlorid (corrosive sublimate)

This white, dry, crystalline substance may be secured on the market in tablet form, one tablet dissolved in a pint of

water making a 1 to 1,000 solution. This is used entirely as a disinfectant, either for soaking seed potatoes for controlling scab and black-scurf, or for treating wounds on trees produced by pruning or by canker removal.

The dilution is generally 1 to 1,000. This can be secured by using the tablets or by dissolving 2 ounces of the powdered material in 15 gallons of water.

Mercuric bichlorid is a deadly poison and must be kept out of reach of children and used with caution.

Coons, of the Michigan Agricultural Experiment Station, reports that a 1 to 1,000 solution of cyanid of mercury can be used as a substitute for bichlorid of mercury, and it is just as effective, easily soluble in water, and not corrosive to metals.

F. C. Reimer, of the Oregon Branch Agricultural Experiment Station, found that a mixture of corrosive sublimate and mercuric cyanid with water was more valuable than either alone for disinfecting tools and cuts in blight-eradication work. The formula is as follows:

Corrosive sublimate	1 oz.
Mercuric cyanid	1 oz.
Water	4 gals.

This makes a 1-1-500 mixture. Gardner, of the Michigan Experiment Station, suggests glycerine instead of water, as it makes a non-freezing mixture which can be more conveniently used in winter.

Hot water and steam

Hot water and steam are valuable as disinfectants and as sterilizing agents. Their application is somewhat troublesome but valuable in greenhouses in which the soil has become badly infected with nematodes, bacteria and fungous spores. It has been reported that the cost of steam cooking does not exceed that of hand weeding untreated soil. The methods followed are described in Chapter X.

SPREADERS AND STICKERS

Recently these materials have assumed an important place in discussions of spray materials, because of the introduction of various milk products with adhesive or spreading qualities. It has long been known that suspensions containing small-sized particles adhere better than those with larger particles, and

FIG. 11.—Smooth film of spray due to spreader.

that an evener distribution of the spray over the leaf tends to increase adhesiveness. This is especially important with fruit or foliage which has a waxy surface on which spray material usually collects in spots. Soap, oil emulsions, and glue have been the standard materials, but they were often undesirable because some, like soaps and oils, could not be combined with certain sprays, such as lime-sulfur. Some could not be used easily—glue, for example, needing to be dissolved in hot water. Oil emulsions frequently burned foliage when employed as stickers or spreaders in foliage sprays. Since 1920 much work has been done on the use of milk products, casein being the

principle which gives the sticking quality. Alvah Peterson, of the New Jersey Agricultural Experiment Station, shows[1] that casein is not nearly as efficient a spreader as soap or oil. Comparing the effects of soaps, oils, and casein-lime mixtures on lowering of surface tension, by the drop-weight method, he found that oil was about twice as effective, and soap about four times as effective as casein-lime mixture. The most common commercial form of casein spreader is calcium caseinate, a mixture of hydrated lime and casein. (Figs. 11, 12.)

FIG. 12—Coarse drops formed by spray applied without a spreader.

While there is not perfect accord among the scientists on the merits of the various milk products, field tests in all parts of the country have shown rather definitely that casein products have many valuable sticking and spreading qualities. The Oregon Agricultural Experiment Station reports that caseinate spreaders when combined with lead-arsenate and concentrated lime-sulfur sprays materially delayed the reaction between these two spray materials, lessening the formation of sludge; that spreaders gave a more uniform coat in late sprays, minimizing the frequent uneven coloring of highly colored varieties of apples, so undesirable and sure to occur if spraying is blotchy; that spreaders increased the number of trees sprayed with a given amount of solution; and finally, that casein spreaders did not decrease the toxicity of the arsenates. However, the Oregon Station

[1] N. J. Agr. Exp. Sta. Rept., 1919, pp. 428-433.

points out that attention must be given to the order in which these materials are placed in the tank, stating that the lime-sulfur should first be diluted to spraying strength, the casein spreader added, and finally, just before application, the lead arsenate should be sifted into the spray. Many other stations concur in these recommendations regarding both the efficacy of the casein spreaders and stickers and the order in which they should be placed in the spray solution.

On the other hand, a few experimental trials have given negative results, some indicating that casein lessened the toxicity of both the insecticide and the fungicide. Thatcher and Streeter[1] conclude that though one brand of calcium caseinate gave a slight beneficial effect in preventing the mechanical losses of sulfur from lime-sulfur the first week after application there seemed to be no conclusive evidence that the protective effect extended further. They showed, though, that losses of sulfur from lime-sulfur ranged from 45 to 75 per cent without calcium caseinate, and from 30 to 57 per cent when calcium caseinate was added.

Considerable work is being done with these materials and their development should be watched carefully by growers.

Calcium caseinate

This is a very finely ground mixture containing about 20 per cent casein and 80 per cent of hydrated lime, and is on the market under such trade names as Kayso and Spreado, and may well be combined with bordeaux mixture, lime-sulfur, and arsenical sprays. Recommendations vary between 1 and 2 pounds to 100 gallons of diluted spray.

Skim-milk

The Oregon Station has shown that two quarts of sweet skim-milk may be used in place of one-half pound of calcium

[1] Thatcher, R. W., and Streeter, L. R., N. Y. (Geneva) Agr. Exp. Sta. Tech. Bull. 116. 1925.

cascinate in mixing wettable sulfurs. It is also recommended by many other stations as a spreader and sticker for general sprays, to be used at the rate of 1 gallon to 100 gallons of spray.

Powdered skim-milk

This article is made up by a large number of manufacturers and can be purchased for 6 to 10 cents a pound. There is some variation in the efficiency of different brands. The New Jersey Agricultural Experiment Station has found that any powdered sweet skim-milk in a finely divided form is just as efficient as the commercial calcium caseinates, when used pound for pound in their place. Some brands failed to exert any appreciable spreading qualities, or did not increase the suspensory qualities of the solution, due principally to coarse physical properties.

Resin

Resin (rosin) is used in bordeaux mixture as a sticker and also in a resin wash for spraying plants with waxy leaves. Resin-fish-oil soap has high sticking qualities. Resin has not the wide application which casein has, due to the difficulty with which it is mixed with water.

Flour

Flour and bill-board paste are excellent spreaders and stickers, especially because, in addition to their sticking qualities they have no chemical reaction with the spray solution, so are perfectly safe with all solutions. The grade of flour used is very important. There are appreciable differences in the efficacy of the flours, and grades having at least 12 per cent gluten-content are to be recommended. This is reached in the common brands of bread flours, but is not found in pastry flours or in some of the coarser flours approaching middlings which are used for feed.

Dried forms of bill-board and paper-hangers' paste are on the market, but they must be mixed with hot water to get them into solution readily. Specially prepared steamed pastes are also sold in barrel lots or smaller quantities by paint and paper dealers. These will mix readily with cold water and are much easier to handle.

The following dilutions are recommended:

	Lbs. to 100 Gals. Dilute Spray Solution
Flour	1-2
Dry bill-board paste	1
Steamed solution paste	2

Glue is an excellent adhesive and has some spreading qualities, and may be used in all kinds of spray solutions. It is applied at the rate of 1 ounce in 100 gallons of diluted spray material.

Soaps, where possible to use, are the best spreaders on the market, having several times the spreading qualities of casein. They also have fair sticking qualities, bringing the layer of spray material into more intimate contact with the leaf than any other substance. They are incompatible with lime-sulfur solutions, most bordeaux mixtures, acid lead-arsenate mixtures, wettable sulfurs, and calcium arsenate. For nicotine sprays, however, they are without equal. The usual dilution is from 2 to 6 pounds to 100 gallons of diluted spray solution.

Miscible oils and oil emulsions are very little used as spreaders and stickers because of their incompatibility with many sprays, and because they are inclined to burn tender foliage. One-half gallon to one gallon of the emulsions to 100 gallons of diluted spray solution is recommended when they can be used safely.

CHAPTER VI

SELECTING THE SPRAYING MACHINE

THE selection of spraying machinery is a problem of utmost importance to the gardener and fruit-grower. Spraying requirements for the different crops become more exacting each season, and the demands on the equipment become correspondingly more severe. In an effort to meet these demands the manufacturers have put on the market a long line of machines varying in worth. Many are of excellent design and sturdy construction and are giving satisfactory service to their owners. Some, however, have been constructed to meet price requirements rather than to give real service, and they have some cardinal defects such as insufficient capacity and power, flimsy construction, and a minimum of refinements. In this field are many opportunities for standardization in the methods of design and construction, number and type of machines, and in calculating and stating pump capacities. It developed recently that one manufacturer, through changes in engines, pumps, and combinations of equipment, was prepared to offer fifty-five different outfits to the growers. It seems reasonable to believe that possibly a large proportion of these models is unnecessary. At any rate, considerable study must be given to the problem if the ones best adapted to the needs of the farmer are to be selected. To a salesman every machine in his own line is a good machine. The wise buyer will weigh certain points carefully before making a purchase.

FACTORS INFLUENCING CHOICE OF SPRAYERS

Before looking into the details of the type and construction of a spraying machine, a number of general considerations

must be taken into account in purchasing a sprayer; *e.g.*, acreage to be sprayed, age and size of trees or plants, frequency of applications, length of time within which applications must be made, convenience of the water supply, character of the surface over which the sprayer must be moved, labor supply, and possibly the grade or character of labor available to operate the machinery.

Acreage to be sprayed

One sprayer of a given capacity can do only so much work in a day. Within certain limits the acreage which can be covered increases with the capacity of the machine. A power-sprayer which at optimum speed will operate one spray-gun and which can be refilled from a convenient water supply will generally be sufficient to cover in ten hours about 250 well-grown fifteen- to twenty-year-old trees requiring 5 to 7 gallons of spray apiece. In other words, the maximum capacity of one spray-gun, when the water supply is convenient, is just about 1,500 gallons a day. A power-sprayer capable of carrying two spray-guns at optimum capacity will be sufficient to cover 500 such trees in ten hours with two men spraying. If the trees are smaller, requiring possibly 3 gallons to a tree, the number which can be covered will be increased proportionately. In calculating his sprayer requirements the wise orchardist will allow plenty of leeway for both rainy and windy weather. Frequently high winds prevail during certain parts of the day, and if convenient, spraying should be abandoned for those periods. It is a rare locality, in the eastern part of the United States at least, that can safely count on more than four spraying days (forty hours) a week.

A potato field requires about 100 gallons to the acre. When four rows are sprayed at a time, with three nozzles to a row, each nozzle having a capacity of three-fourths to one gallon a minute, about twelve acres can be covered in ten hours with average conditions.

Age and size of trees

This factor follows closely the preceding topic. It may well be brought out, however, that it takes longer to apply a 200-gallon tank of spray to fifty small trees than to twenty-five large ones, due to the extra walking required and to the distance between trees. Small trees can be easily sprayed with spray-rods, operated on equipment smaller than that necessary for the operation of a spray-gun. In the same way small patches of field crops can be handled with lighter equipment which would not carry as many nozzles or spray as many rows at one time.

Frequency of applications

Some crops need to be sprayed only rarely, and considerable time may be available for each spray. Under these circumstances the grower can get along with equipment of lower capacity than would be required were constant spraying necessary.

Time available for each application

This is a factor of first magnitude and too often is underestimated when laying out the spraying program. It also is related to the preceding topic. When the development of pests is of such a character as to demand a quick coverage in order to save crops, it is essential to have enough equipment to apply the coatings at the proper time. This is especially true in combating insect pests for which spraying is delayed until the insects actually appear. On the other hand, if coatings are being applied at certain definite intervals as is frequently done in disease control, and there is no rush of work, much smaller equipment may suffice.

This can well be illustrated by citing the protection of peach trees with a combination of spraying and dusting practices. The peaches must be sprayed in the dormant season in most

sections for peach leaf-curl. This operation can be carried on at any time during favorable weather from the time the leaves drop in the fall until the buds begin to swell in the early spring. With ample time available a grower can cover a very large acreage, even with a hand-pump if necessary. Then in the growing season his protection is secured by the applications of dust, by which large areas can be covered in a very short time. At the farm in which the author is interested, all of the applications during the growing season are made with a dusting machine so that only the dormant application is left for the liquid-sprayer. Ample time is available for the delayed dormant spray to be applied to sixty-five acres of twenty-seven-year-old apple trees with one sprayer capable of operating only one gun, while it would require at least two, and possibly three, such machines, with men and teams, properly to cover the trees during the growing-season, especially from the time of the pre-pink spray to the application coming a month after petal-fall, where only seven to ten days elapse between coatings.

Convenience of water supply

Few growers are aware of the amount of time actually spent refilling the sprayer. In many orchards this operation actually consumes one-half of the time available for spraying. This statement is made only after years of observation in hundreds of orchards in different parts of the United States. When two guns are operating from one rig, it will require from twenty-five to thirty-five minutes to empty a 200-gallon tank. If the water supply is one-quarter mile away (and that is a reasonably short distance when figured from the outlying portions of moderate-sized orchards) at least ten minutes are spent in making the round trip, exclusive of the time consumed refilling. When the water supply is even more distant, this time is increased. At the author's own orchard the output of spray materials from one machine was increased from eight to

eleven tanks a day by the erection of a large storage tank in the center of the orchard.

Saving of time may be effected by more convenient arrangements for refilling, whether by gravity, dipping, or pumping through a refiller; and the availability of the spray materials. Any contrivances which speed up the operations of measuring out the ingredients and hasten the refilling operation make for a reduction in the total amount of equipment necessary to handle any given block of trees or other plants.

Terrain over which sprayer must be moved

If the farm is hilly or stony or cut up by stone rows or gullies, spraying operations will be slowed down, and proportionately more equipment will be required to cover the acreage. In case of steep hills it may be necessary to use tanks holding only 100 or 150 gallons of material, making stops for refilling more frequent.

Labor supply

Often the labor supply is limited, making it advisable to use a few very large outfits instead of a larger number of more mobile smaller ones, thus saving teamster labor. Shortage of labor may make it advisable to use dusting machines for at least a part of the applications so that the spraying program will not lag.

Quality of labor available

When the owner himself is to use the sprayer this operation becomes much more efficient, and it will usually pay to secure the best machinery available. Where only a very low grade of labor is used it may be unwise to equip the farm with complicated machinery. In some sections of the country the use of the hand-sprayer has persisted because it has been unfeasible to purchase power-sprayers for the class of help it has been possible to secure. Wherever possible the owner should work

with the spray crew, as his presence will speed up the operation, and the work will be done more thoroughly, and the machinery will receive better care.

THE SELECTION OF SPRAYING EQUIPMENT

When all of these factors are weighed, then the grower is ready to turn his thoughts toward the selection of his spraying equipment. Here, also are important considerations to be taken into account, such as capacity of pump in gallons a minute, construction of pump, simplicity, weight of machine, and type of the power-plant. Whether the machine is of the smallest size and for the simplest work, or one of the largest park sprayers, these same points must be considered.

Styles and sizes of liquid-sprayers on the market range from the atomizer to the park sprayer, and fit the requirements for all purposes and acreages. However, there are two general classes of growers, one being the amateur or backyard gardener and the other the commercial or professional gardener and orchardist. Therefore the machinery will be grouped in two classes, the first including machinery suitable for use on small plants and gardens for the amateur and small grower, and the second including machinery primarily useful to the commercial grower on large plantings.

Machinery suitable for small gardens and plants

In this class fall the various hand-pumps such as the atomizer, bucket and barrel-pumps, and accessories with which small plants can be sprayed. Even large trees can be coated in a fairly satisfactory manner with the larger hand-pumps.

The atomizer (Fig. 13)

This is the smallest type of hand-sprayer. It is used mostly for treating small plants in the house or home garden. It consists of an air-compressing pump fastened to a small tank or reservoir. When the air is compressed it is passed over the

end of a tube which extends down into the spray material, sucking some of it up and blowing it out of the nozzle end of the atomizer with the blast of air, which breaks it up into a mist. No high or sustained pressures can be maintained. Agitation is secured by the shaking incidental to the pumping. The best atomizers are made of brass, although cheaper metals are also commonly used.

The greatest convenience of the atomizer is in its lightness and small capacity, it being very effective against aphis, mildew, slugs, and the like, on roses, young trees, or other plants. Householders also use it for disinfecting chicken-houses and dog-kennels. The capacity of the reservoir varies from a pint to two or three quarts.

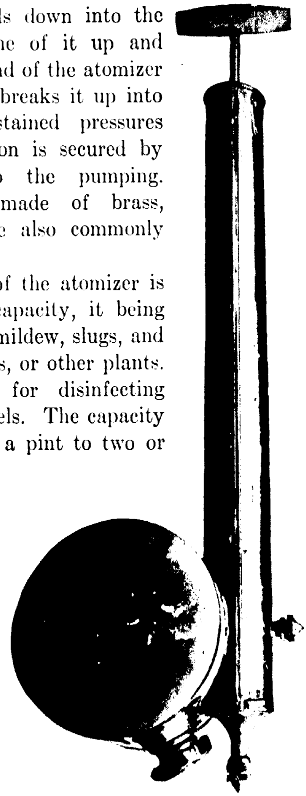


FIG. 13.—Atomizer type of hand-sprayer.

The bucket-pump (Fig. 14)

This pump also is designed for dooryard spraying. It consists merely of a single- or double-acting pump which may be clamped into any ordinary bucket, the bucket being the reservoir for the spray. The single-acting pump has one cylinder and exerts pressure only on the down stroke, while the double-acting pump has two cylinders, pressure being exerted in one cylinder on the up stroke and in the other on the down stroke, thus maintaining a more or less even pressure. Agitation is

sometimes secured by a small jet of spray forced through an orifice at the bottom of the pump into the material in the pail. This pump is best made of brass, is very light and easily handled, and will develop sufficient pressure to spray bushes and even low trees. The double-acting pumps are more satisfactory. It must be admitted that the operation of the

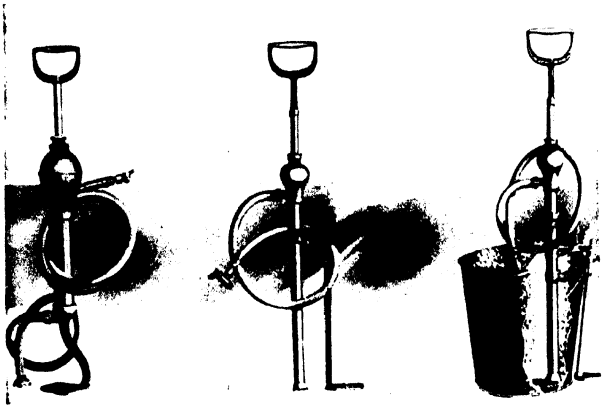


FIG. 14.—Two types of bucket-pumps. The one on the left is not placed in the container, but the lower hose is dropped in. The figures on the right show the other type and method of attaching it to the bucket or tub.

bucket-pump is not at all simple, and many an amateur gardener has been discouraged by the struggle with this outfit. However, for the suburban dweller with a small garden and a half-dozen low trees of assorted varieties, this is perhaps as satisfactory a spray outfit as can be secured.

The knapsack-sprayer

This sprayer has certain advantages over the bucket-pump when much moving about must be done in spraying, in that it is equipped with straps and is carried on the back of the

operator. The most common type is merely a pump with a large air-chamber and agitator, mounted permanently in a three- to five-gallon tank, the handle of the pump extending over the shoulder or under the arm of the operator, making it possible to pump with one hand and spray with the other. This operation is more laborious than it sounds—which is the real disadvantage of this outfit. The material slops around over the operator to a certain extent, and the tank is a con-

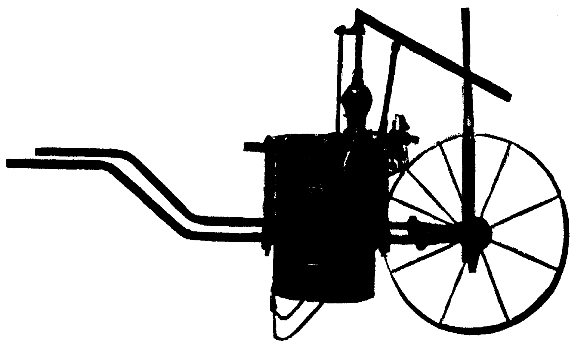


FIG. 15.—Wheel-mounted traction sprayer.

siderable burden when full. For special work such as repeated applications of nicotine spray on one- or two-year-old trees, only a portion of which may be infested with lice, it makes a convenient implement. It also has its uses in row spraying on vegetables. If someone is available to do the pumping the bucket-pump or barrel-pump, with a little longer hose, is probably the more practical dooryard sprayer (Fig. 15). All parts of the knapsack-sprayer which are touched by spray should be made of brass. There are types of knapsack-sprayers on the market which work on the principle of the syringe or atomizer, the pump being located on the outside of the tank and connected to the bottom of it by a hose.

The compressed-air hand-sprayer

This is of much the same capacity and for the same service as the knapsack-sprayer, but with entirely different pump principles. It consists of an air-pump, preferably brass, mounted in an air-tight chamber, which is filled three-quarters full with the spray material, pressure being secured by pumping air into the tank, thus forcing the spray out under pressure. Frequent pumping must be done to keep up any pressure when the tank is nearly full, but as the tank is emptied of spray the effect lasts longer. Considerable force can be developed, providing frequent enough stops are made for pumping. The tank, usually holding from three to five gallons, must be well constructed, because of the high pressure exerted on it. Brass is the best material for wear and should be heavy enough to stand strain. Agitation is secured by the movement of the operator. On the whole, it is not as satisfactory as the other types of hand-pumps.

For some years large compressed-air sprayers were on the market and were quite popular, especially before the perfection of the modern light powerful gas-engine sprayers. A large high-pressure tank received compressed air from a stationary air-compressor. A tank of similar size mounted at its side received the spray material. Valves connected the two tanks and the air pressure was fed into the spray-tank, thus forcing out the spray under pressure. The pressure steadily diminished as the tank was emptied.

The advantages of these outfits were that they were light, simple, inexpensive to operate, less liable to breakdown, and concentrated the engine work and the filling all at a central station. The difficulties in agitating the material in the tank, the introduction of the spray-gun with its high pressure requirement, and the perfection of the power-sprayer have driven the compressed-air sprayer off the market until only a few are used at the present time.

Another compressed-air or atomizer type of sprayer is on

the market in which the air and materials are not confined in tanks at high pressures, but are pumped under low pressures to the nozzles where the air current atomizes the spray into a fine mist. The solution is confined under five to ten pounds pressure, but the air current flows constantly from a rotary air pump through a hose to the nozzle at a maximum pressure of twenty pounds. Manufacturers claim great durability for this type of outfit due to the low pressures carried and the

FIG. 16.—The liqui-duster. The spray is discharged at low pressure through a nozzle in the end of the blower-pipe, and a blast of air from a fan drives it onto the tree, breaking the spray into a fine mist.

complete breaking up of the spray solution into a mist by the air current. This type of machine, while only in limited use, has received favorable criticism.

The "liqui-duster" is an innovation of 1925. A powerful fan forces air through a delivery pipe, similar to that on a dusting

machine. The solution is sprayed into this pipe, and thus the spray is blown on to the trees. The advantages claimed for the machine are that it is as fast in operation as a duster, that absence of a driving spray lessens the danger of burning, and there are no hose and nozzle troubles. (Fig. 16.)

The barrel-pump

This consists of a powerful pump with a long handle which can be mounted in a barrel, and with which a pressure of 75 to 125 pounds can be maintained with a discharge of 1 to 3 gallons of spray a minute. This is sufficient to run one lead of hose having one disc-nozzle with a 3/32-inch aperture in the disc. The use of any smaller aperture reduces the drive or carrying power of the mist, and results in less efficient work. The pump should have a brass cylinder from 2 to 2½ inches in diameter, and a stroke of 3 to 4 inches. It should have an air-chamber which will help to maintain even pressure even though the pump operator rests for a moment. It should be easily attached to or removed from the barrel. This is facilitated if the pump is fastened to the barrel by clamps rather than by screws or bolts.

The valves at the base of the pump should be easily accessible in case clogging necessitates their removal. If the pump packing can be tightened without removing the pump from the barrel it is desirable. Variable adjustments at the attachment of the handle to the pump, to give varied leverages, are of value so that the work can be made lighter for less sturdy operators. The agitating paddles should be large with a wide sweep.

The barrel-pump may be mounted in several ways (Fig. 17). It is commonly placed upright in a 30- to 60-gallon barrel, the head of which has been partially cut out, although frequently pumps are mounted in barrels laid horizontally. A large pump is generally mounted in the vertical barrel, giving higher

pressure than a small pump mounted horizontally, and is usually a little easier to operate.

The barrel-sprayer was for many years the only commercial orchard sprayer, and it is still used to a considerable degree in the less-developed orchard sections. A case is known by the author where today a peach orchard of approximately 5,000 trees is being sprayed entirely with a barrel-sprayer. However, its use is now generally confined to the small grower who can spray possibly an acre or two of field crops or a hundred or more peach trees, and perhaps twenty-five to fifty mature apple trees with it. Larger blocks can be sprayed with a barrel-pump, but for larger acreages the grower should afford power equipment. The barrel-sprayer is also useful in applying whitewash and disinfectant to barns and chicken-houses.

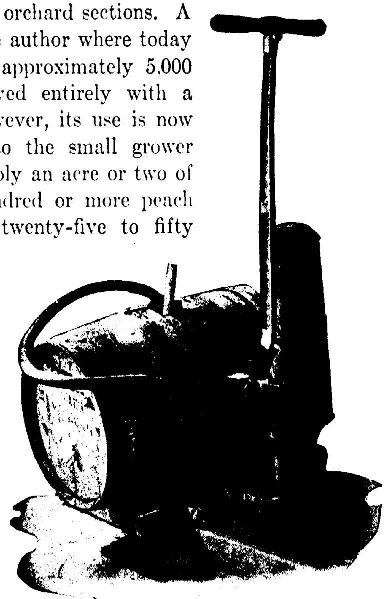


Fig. 17.—Two-cylinder hand-pump mounted on wooden skids.

The barrel-sprayer can be dragged on skids, carried on a wagon, or mounted on two wheels with large wide tires. For garden use a 30-gallon barrel mounted vertically on such wheels makes a convenient —though usually not too sturdy—outfit which may be moved by hand.

The operation of any barrel-sprayer is heavy labor. One

stout man is needed to do the pumping and another for the spraying. If sustained work is to be done the operators should exchange jobs occasionally.

The double-action hand-pump, two-cylinder hand-pump, or tank-pump (Figs. 17 and 18)

This pump is a hand outfit which is mounted on a platform. It has a vertical handle which enables the operator to exert his efforts more easily and with more telling effect. The spray material is drawn into the pump by means of a suction hose from a tank, which may consist of anything from a single barrel to a regular 200-gallon spray-tank. This type of pump has one or two cylinders, as the case may be, of 2 to 2½-inch bore, and a 3- to 4-inch stroke. The double-acting pump has only one cylinder, but is so constructed that pressure is exerted when the handle is moved in either direction. Two-cylinder pumps are mounted horizontally, (or "double opposed," as it is called) or vertically, with a rocking beam connecting the pistons and handle. If the handle is adjustable so that pumping may be done with the handle either in a vertical or in a slanting position, the operator finds it less tedious because he can change his position at frequent intervals.

Because of the greater leverage and larger pump capacity, considerably more work may be done with these than with the ordinary barrel outfit. Only one lead of hose can be supplied, but pressures of 125 to 175 pounds can be maintained with two small disc-nozzles having a combined capacity of two to three gallons a minute, with one husky operator pumping.

The use for the tank-pump is in the small orchard, vineyard, or garden, where only an acre or so is to be sprayed, and it does not fill the place of even a small power outfit. It is a somewhat more expensive and more easily operated type of barrel-sprayer and should be purchased when the ownership of a power-sprayer is not practical.

Machinery primarily useful to the commercial grower

When large numbers of plants are to be sprayed, hand equipment becomes merely a makeshift. The power-sprayer

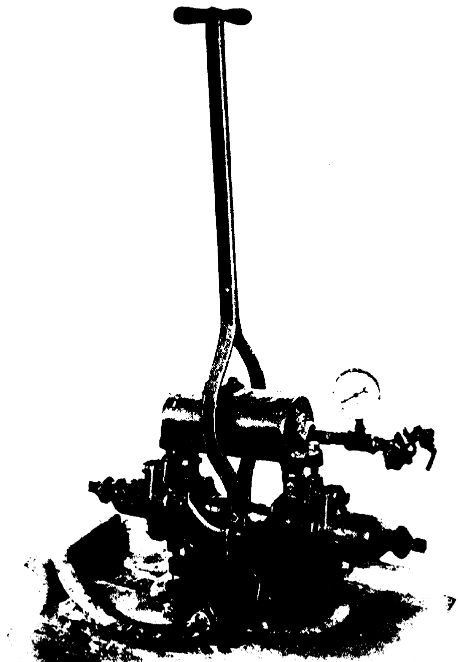


Fig. 18.—Two-cylinder hand-pump which can be mounted on a skid or on a tank.

is the only type of machine to be seriously considered by the commercial grower, even though his holdings comprise only a few acres. Under this classification come the traction-

sprayer and all of the engine-driven and compressed-air sprayers.

The traction-sprayers

This type of pump takes its name from the method by which pressures are developed. Broad-tired wheels with gears attached operate one-, two-, or three-cylinder pumps. The chief advantage of this type of machine is the simplicity of operation and small expense. Pressures reaching as high as 250 pounds can be maintained, providing the rig is in constant motion. The chief disadvantages are that as soon as the team stops, the pressure rapidly diminishes and cessation of agitation allows the spray material to settle. Consequently this type of outfit is undesirable for orchard work, as a stop should be made at every large tree while the operator finishes the spraying. This disadvantage can be overcome to some extent by spraying one side of the tree only while passing up the row, and covering the other side of the tree on the return trip. However, this involves some extra driving and frequently results in the operator leaving a tree before it is completely finished. In applying sprays for such insects as leaf-hopper and aphis, where special attention must be paid to spraying the under side of the foliage from a position under the tree, the operator is at a disadvantage if the team keeps moving.

The best use for this machine is in the spraying of field crops, such as potatoes, tomatoes, and melons, and such fruits as grapes and berries when it is not necessary to make any stops. For such work, pressures of 125 to 200 pounds should be developed, and the capacity of the machine should be great enough to supply six to twelve disc-nozzles, each having a capacity of approximately one gallon a minute. Thus the total capacity of the machine must be approximately 12 gallons a minute.

The traction-sprayer is usually mounted on two wheels, to the axle of which is bolted a bed upon which are balanced the

pump and tank. It is customary to put the pump in front, and when the tank is empty much of the weight of the machine is borne on the tongue or shafts.

In operating the traction-sprayer, skill is required in gauging the speed of the team. Inasmuch as the flow of the material is constant, if the team moves too swiftly there is danger of slighting the spraying. The team should move fast enough to keep up the pressure and yet not too rapidly for a thorough coating of the plant. The tank capacity ranges from 100 to 200 gallons. The 100-gallon size is the most common.

The power-sprayer

The power-sprayers, so called because the pumps are driven with engines, are the most satisfactory for the commercial orchardist and gardener. Ranging in size from a small inexpensive one-cylinder outfit with a capacity of 3 or 4 gallons a minute to the more elaborate machines used in large orchards or in spraying shade trees and parks, the grower can find a machine of a size to suit every need. The advantages of the power-sprayer are many. Pressure is constant. High pressure may be developed. Materials are kept agitated. The large capacity enables the operator to use modern spray-guns which will coat the more distant parts of the trees thoroughly. Two leads of hose may be used on large capacity machines. The disadvantages are that the machines are complicated, expensive, and heavy. However, the advantages far outweigh the disadvantages.

The smallest machines have only a one-cylinder pump with a bore diameter of 2 to 2½ inches and a stroke of 2½ to 4 inches, and are run by 1½- to 2-horsepower engines. The maximum capacity is about 5 gallons a minute at 250 pounds pressure, while the usual capacity is from 3 to 4 gallons. This will supply one lead of hose with a spray-rod and two disc-nozzles with a combined capacity of about 3 gallons a minute, or a spray-gun with a disc orifice not to exceed 5/64 inch, and

having a capacity of approximately 3 gallons a minute. The average one-cylinder pump will not carry a spray-gun with a large outlet aperture when the nozzle is opened wide without a sharp drop or great variations in pressure.

The spray machine with a one-cylinder pump has a narrow *field of usefulness*, and its place is on the farm where *less than five acres are sprayed*. With such a *small aperture the gun* will cover low growing plants where no drive is required of the spray, but it will not reach up into tall trees. Beyond 10 or 12 feet the spraying becomes inefficient. However, it is suitable for spraying row or field crops where lower pressures can be used and where nozzles with small apertures are common. Occasionally a one-cylinder pump is found large enough to deliver 5 to 6 gallons at 250 pounds pressure, and this will carry a gun with an aperture in the nozzle of 7/64 to 1/8 inch in diameter. If operated by a 2½- or 3-horsepower engine it should be entirely satisfactory.

Two-cylinder outfits are offered by almost all manufacturers. Pump dimensions for each of the cylinders are also from 2 to 2½ inches in diameter, with a 2½- to 4-inch stroke. Engines of 2- to 4-horsepower are used, and the total capacity of these outfits ranges from 5 to 12 gallons a minute at 250 pounds pressure. Almost every two-cylinder outfit will carry a spray-gun with a disc having a 7/64- to 1/8-inch aperture, while one or two of the largest type will carry two such guns wide open, providing the machine is in perfect running condition.

The writer knows of no two-cylinder orchard pump on the market today which will under average conditions carry more than one gun. An occasional machine will run two for a short time after being primed for the trial, but it will not maintain it under commercial use.

The two-cylinder power-pump has quite a range of adaptability, and is generally a satisfactory type of sprayer on acreages which can be covered by one operator in the time

available for that special spray. It is much better than the one-cylinder pump, maintaining an even pressure when used within its capacity, and is valuable for spraying a considerable

FIG. 19.—Desirable type of power-sprayer for large orchard. Note the sturdy steel frame, underslung tank, large, wide-tired rear wheels and small front wheels which will cut under the frame, making short turns possible. There is sufficient capacity to operate two guns at high pressure; 2,000 gallons a day should be put out easily by such an outfit.

acreage of field crops. It is somewhat limited as an orchard sprayer, being useful for spraying perhaps as many as 750 fifteen- or twenty-year-old well-grown apple trees or 1,500 bearing peach trees.

The larger power-sprayers (Fig. 19) usually have three cylinders, with cylinder diameters ranging from 2 to 3 inches with a stroke of $2\frac{1}{2}$ to 4 inches, and capacities varying all the way from 10 to 25 gallons a minute. Most frequently these machines are driven with a $3\frac{1}{2}$- to 6-horsepower engine and have a maximum capacity of 12 gallons a minute at 250 pounds pressure. They will carry one spray-gun easily, and the best of them will run two leads of hose with two spray-guns wide open when they are in good running order. The largest orchard spraying outfits generally have from 6- to 15-horsepower engines with capacities of 15 to 25 gallons a minute. These will carry two and even three leads of hose with spray-guns attached and are the most practical outfits for growers who wish to carry more than one lead of hose.

There are also high-power sprayers, having from 15- to 35-horsepower engines, on the market which are used largely for shade-trees and park spraying where pressures as high as 600 pounds at the pump are sometimes required to drive a heavy stream through several hundred feet of hose.

Three-cylinder power-pumps have correspondingly greater possibilities than the two-cylinder. However, the fact that the pump has three cylinders does not insure the delivery of sufficient material to do more work than a large two-cylinder pump. In fact, the general run of three-cylinder machines on the market today have not quite enough capacity to operate two guns with nozzle apertures of 7/64 to $\frac{1}{8}$ inch each. The larger ones will deliver more material than two-cylinder pumps, and are therefore more satisfactory because they maintain more even pressures and have a greater reserve, and they do not have to run at maximum capacity at all times, thus insuring longer wear. They will also operate more nozzles in spraying row crops. The field of usefulness depends on the capacity of the pump. If this is large enough to operate two guns steadily, then, as far as the orchardist is concerned, it has almost twice the range and efficiency of a machine which will operate

one gun. If a three-cylinder machine is needed, one which will actually deliver 12 to 15 gallons a minute at 300 pounds pressure is the most economical because two leads of hose can be attached whenever wanted, and the machine will not be taxed to its utmost capacity to supply them. It should be operated by an engine of at least 5 horsepower.

Some very large orchard sprayers are now on the market having a capacity of 15 to 30 gallons a minute at pressures of 300 to 600 pounds. They are equipped with 300- to 500-gallon tanks. They are usually operated by 5- to 15-horsepower engines. Where the ground is level and these machines can be pulled, they are very economical, as two, three, and even four leads of hose can be attached and as much work done as would be accomplished by two or three small outfits, making possible considerable saving of teamster labor. The disadvantage of this machine is that if it breaks down a larger number of men are idle, although this is somewhat compensated for by the fact that one large machine is not liable to break down as frequently as two or three small machines combined. Another disadvantage of the large machine is that it is difficult to pull through the orchard in the spring when the ground is wet, or where it is hilly or sandy. This is being overcome somewhat by constructing machines with under-slung tanks and high wide-tired wheels, which do not sink in as readily as small narrow-tired wheels. Engines and pumps of these larger capacities are also suitable for use as stationary pumping plants when the orchard is piped for this system of spraying.

The park sprayers have only a limited use. They have extremely high-pressure pumps, usually with three or four cylinders operated by 10- to 25-horsepower engines. These outfits are often mounted on auto-trucks and power for pumping may be taken off of the crankshaft of the motor. These trucks rarely have to go on rough or soft ground, long leads of hose enabling the operators to spray distant trees. This

same type of sprayer is used in browntail and gypsy-moth control work. In spraying the trees on the mountains behind Somerville, New Jersey, for this latter insect, occasionally leads of 3,000 feet of hose were operated, requiring 600 pounds pressure at the pump to give 200 pounds pressure at the nozzle.

Applying the foregoing points to actual cases, let us assume that a man has ten acres of mature apple trees, or possibly 500 trees. This acreage can be covered by one machine operating one gun in probably two and one-half to three days. Therefore any machine with ample capacity to operate one gun would suffice.

Assuming that the man had 25 acres containing 1,250 mature apple trees, he would need equipment to cover this acreage in four days, because there are times in the apple spray schedule when applications come from seven to ten days apart, and only about four good spraying days can generally be expected out of seven. One very large machine capable of operating two guns at full capacity, with which 500 trees can be sprayed in one day, would be the least equipment he should have. This same equipment would suffice for perhaps 10 additional acres, when he would have to add another smaller machine capable of handling one gun. He would then be equipped to spray up to 50 acres containing 2,500 trees. If the acreage reached 60, he would then need two large machines. However, in sections in which curculio and scab are not prevalent and the orchard needs to be covered only at intervals of possibly two weeks, one large-sized machine would be sufficient.

The grower with 25 acres of peach or sour-cherry trees would not need the same large sprayer required by the man with 25 acres of mature apple trees. The peach and cherry orchard would have possibly 2,500 trees, while the apple orchard would contain only 1,250 on the same land; but the 2,500 cherry or peach trees would require only between 5,000 and 7,500 gallons of spray at each application, while the 1,250 mature apple

trees would require between 7,500 and 12,000 gallons. A smaller sprayer capable of operating only one gun would cover these peach or cherry trees in six to eight days, and they are rarely sprayed at closer intervals than two weeks.

The man with 50 acres of young orchard, possibly two or three years old, may be puzzled over the size of sprayer to buy for aphis and scab control. The trees will be small and will bear little for possibly four to five additional years. He would be justified in getting a machine operating only one gun under those circumstances, adding the larger machine five years later when conditions demand it, using the smaller machine thereafter as an auxiliary. If the same man had only 15 acres of such young trees, he would then want to get the same one-gun machine that he will require four or five years later when the orchard is in bearing.

CHAPTER VII

QUALIFICATIONS FOR SPRAY MACHINERY

REGARDLESS of the size of sprayer certain qualifications are necessary in every machine. The power-plant, pump, air-chamber, valves, pressure-regulator, agitator, container for the spray material, and some sort of platform, skid, or truck for carrying are common to all power machines, and many of these features are important even to hand-sprayers. There are some requisites which pertain to all of these sprayer parts.

QUALIFICATIONS FOR PUMPS

The capacity of the spray-pump is of utmost importance. The common tendency is for the manufacturers to overrate the capacity on most machines, while growers frequently expect far too much from them and overload them, allowing nothing for reserve. The capacity of a machine is the number of gallons a minute which will be delivered by the pump at a certain pressure, usually 250 pounds. Few new machines will actually deliver the advertised capacities when placed in an orchard.

Capacity

There are a number of points at which there is sufficient wear very soon after the sprayer is placed in operation seriously to reduce the capacity. Valve seats and pump packing which become worn and perhaps slightly leaky, engines which may not run up to the speed required to give the rated capacity, and small leaks or mal-adjustments tend to pull down the delivered capacity. It is safe to say that the average machine,

rated at 10 gallons a minute at 250 pounds pressure by the manufacturer, seldom delivers more than 7 gallons after thirty days of service. Replacement of worn parts will remedy much of this loss, but the grower can afford neither the time nor expense incident to a thorough overhauling at such frequent intervals, while the common tendency is to allow the machine to run until repairs are essential. The modern spray-gun, with a 7/64- or ⅛-inch aperture delivers about 5 gallons a minute when opened. The average spray outfit rated by the manufacturer at 10 or 12 gallons a minute will rarely carry more than one gun after a few days of service and maintain constant pressure, notwithstanding the statement of salesmen. An outfit with a rated capacity of at least 15 gallons a minute is required.

The grower also makes the common mistake of trying to get along with less capacity than is needed to do the work. In selecting a sprayer, the capacity of the pump should always be large enough to allow ample reserve.

Construction (Fig. 20)

The construction of the pump is important. All parts should be accessible and easy to remove, clean, or replace. Brass or porcelain is commonly used for the parts coming in contact with spray materials, brass being corroded less than any of the other metals. Bearings should be large and easily lubricated. The design of the pump should be simple and with as few changes of direction in the flow of materials and power as possible.

. Valves should be given special consideration. There are three general types; the ball, poppet, and disc, the ball valve being the one most commonly used. Poppet and disc valves are flat, and are more difficult to adjust and wear less evenly than ball valves. Bronze is the best material. The valve seats receive much wear and should be easily replaceable. They are commonly made of softer material than the balls so as to

take up the wear. They are made of brass and of various compositions.[1]

Cylinders are of two types. One has a smooth brass or porcelain tube against which an expanding plunger works. In the other type, the tube has a ring of packing at the top which fits closely about the piston to prevent the material from escaping. Brass is most commonly used for cylinders, although porcelain and steel are also employed.

The plungers must be designed for the cylinders in which they are to work. If they work in a smooth cylinder, a washer or ring of packing is fastened on the end of the plunger. On the type of cylinder having the packing fastened in the top, the plunger may be merely a smooth piece of brass or iron tubing working inside the packing. In either case, the wear should

[1] When the engine and pump are started, with the nozzles open, the plungers (4) in the porcelain lined cylinders (3) begin working up and down. The liquid from the tank (24) through the underneath suction (9) follows into the cylinder as the plunger rises. As the plunger falls, the material passes on through the discharge valve (2A) into the lower valve (1) of the pressure regulator. If the spraying nozzles are open the pressure of the liquid lifts the upper or check valve (1C) and forces the spray material down into the bottom of the air-chamber (6) and underneath the diaphragm (1E) of the pressure regulator and on out to the nozzles through pipe (23). With nozzles closed the engine and pump immediately build up the pressure in the air-chamber (6) and hence in the discharge pipe (23) which runs under the pressure regulator diaphragm (1E). Let us suppose that the working pressure is 250 lbs. and the spring (1D) holding the diaphragm down will just balance 250 lbs. As soon as the pressure builds up to 252 lbs., which is instantly after the spraying nozzles are cut off, the pressure overcomes the tension of the spring (1D), raises the diaphragm (1E), and by means of the stem (1F) lifts the lower valve (1) off its seat. The liquid, of course, continues to go on through from the pump, but instead of flowing through the upper valve (1C) of the pressure regulator it now passes through the lower valve (1), which is held off its seat, and flows back through the pipe (1B) into the tank. The pressure on the air-chamber remains at 252 lbs., because the upper or check valve (1C) is closed and there is no way for the pressure to run down. The pump in the meantime is simply taking the liquid out of the tank through the underneath suction (9) and discharging at the top of the tank, the engine running nearly idle.

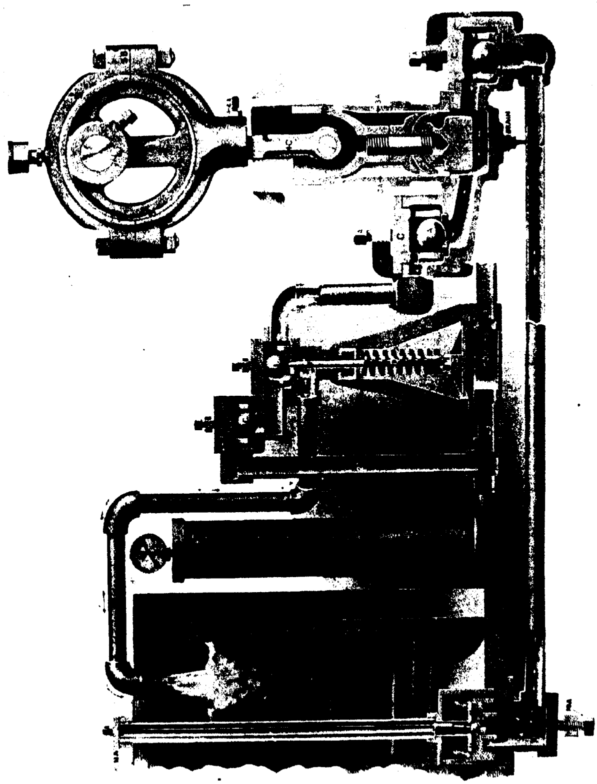


FIG. 20.—Cross-section of pump. Note the working of the pressure regulator. (See footnote on page 134.)

come almost entirely on the packing or on the plunger washer. Constant contact with corroding materials makes it necessary to construct most plungers of brass. The packing and washers should be easily removable and renewable and a supply of these two materials should always be on hand in the tool-box of the machine. Hemp, candlewick, canvas, asbestos, and rubber composition treated with oil, paraffin, or graphite to make them soft, are commonly used for packing.

The method of driving the pumps may be by gear, yoke, chain, or belt. Gear-driven machines are generally considered more satisfactory by orchardists. Unless well mounted on a very rigid frame there is some grinding when going over rough ground. A chain drive is also positive and quite satisfactory. The disadvantage of a belt-driven machine is that the belt often stretches and slips, or breaks, and wears out much more frequently than a chain or gears.

The pressure-regulator is an essential part of the machine. There are two types: the relief valve, which remains open constantly and carries away a certain part of the delivered material; and the pressure regulator which only opens when a certain pressure has been reached. The regulator type is the more desirable of the two. The principle on which it works is the exertion of force on a broad diaphragm which opens a by-pass valve when the pressure reaches a certain point, allowing the escape of the excess material. Manufacturers have perfected the regulators to such a degree that there is practically no variation shown on the pressure-gauge even when the nozzle is rapidly opened and closed, the regulator taking up the load so easily. By tightening the tension on the spring holding down the diaphragm the pressure may be raised. In selecting a pressure-regulator for spraying with 200 to 400 pounds pressure, one with at least 12 square inches of exposed surface is desirable.

The air-chamber is the air-tight reservoir into which the spray material is pumped. The material enters the bottom of

the chamber, and the air is compressed and acts as a cushion in maintaining an even flow to the nozzle. It should have a capacity of possibly 3 to 5 gallons in case of a power-sprayer. This accessory has almost as much to do with the development of even pressure as the pressure-regulator. Allowing the pump to operate for a few minutes before passing the spray material into it will result in a few pounds of air pressure being developed in the air-chamber, and this contributes to the maintainance of more even pressure during spraying. A broad base and not too much height are desirable in a good air-chamber. The pressure-gauge should be mounted on the air-chamber.

Lubrication

Lubrication of the pump is important. The best types have basins at the top of the cylinders which may be filled with heavy oil so that the pistons receive a coating of oil at every stroke. Oil or grease-cups should be placed on every bearing and should be easily accessible and frequently filled. Some manufacturers have built pumps with a central oil-cup with a distribution system feeding each bearing, but these are frequently complicated, expensive and easily damaged.

Feed system

There are two methods of conveying the spray material from the tank to the pump—by gravity and by suction. Suction feed is the most desirable, because in spraying with materials such as self-boiled lime-sulfur or wettable sulfurs in which there may be considerable sediment, the particles are not carried over into the pump. With gravity feed, heavy materials may clog the delivery pipe in case the agitator stops for a few minutes during repairs.

Gravity feed is excellent for solutions containing no sediment. The delivery pipe from the pump to which the hoses are attached should be direct and should end preferably at the extreme rear of the machine, so that hoses may be easily

connected or removed and will not be inclined to drag against the wheels.

Agitation

Most of the spray materials are held in suspension rather than in solution, and it is necessary to keep them stirred up in order to get a uniform concentration of materials when drawing spray from either the top or bottom of the tank. Hand-pumps and knapsack-sprayers usually have wooden paddles or dashers attached with a rod to the pump-handle. Power outfits have three types of agitators. The first is the propeller type, in which two or three metal propellers are attached to a shaft extending across the spray-tank near the bottom and are connected through a universal joint or crank-shaft to the pump. The speed of this agitator should be at least fifty revolutions to the minute for large propellers, and more rapid for smaller propellers. The other type of agitator is the paddle type in which sweeps, extending the whole length of the tank and clearing the bottom of the tank by only a fraction of an inch, are fastened to a shaft running through the tank. The shaft is driven by the engine and the sweeps prevent any sediment from settling.

The agitator does more than merely keep the spray in suspension. A. L. Lovett, of the Oregon Agricultural Experiment Station, showed by some investigations that the physical properties of lead arsenate were improved by reasonably violent churning when coarse particles were present. It broke down coarse particles into finer division, increasing the spread on the foliage and fruit and giving better control of pests.

QUALIFICATIONS FOR POWER-PLANTS

The speed with which traction-pumps are operated will depend on the gear ratio between the wheel and the drive-shaft. This gear ratio can be changed within limits to develop higher pressures, the maximum pressure possible being that

which will not slide the wheel when the tank is about empty. The heavier the outfit and the broader the tires on the sprayer, the greater are the pressures, which may be developed.

Gasoline engines

Practically all power-sprayers are run with gasoline engines, and for most of the orchard types, the one-cylinder vertical engine is used. The mistake made by manufacturers most frequently is that of putting too weak engines on the sprayers. A 2-horsepower engine is the smallest which will give satisfactory service, although 1½-horsepower engines are in use. For the duplex and triplex power-sprayers, engines of 3 to 6 horsepower are necessary. For large outfits delivering from 12 to 20 gallons a minute, a four-cylinder engine has been adopted by some progressive manufacturers. For park sprayers discharging from 20 to 50 gallons a minute, engines of 15 to 35 horsepower are required.

In selecting an engine, lightness, simplicity, and performance should be considered. There are a number of engines now on the market which develop from 4 to 6 horsepower, and weigh about 250 pounds, or about 50 pounds to a horsepower. These represent a marked advance in the construction of engines for power-sprayers. Any spray engine should be simple to operate because labor unfamiliar with gasoline engines must be employed frequently, and it is difficult to explain the operation of a complicated motor. The grower is safer in adopting an engine which has been giving service for a number of years, with the repairs of which he is familiar, than in trying any motor of a new type until it has proved itself under field conditions.

The cooling system on the engine is worthy of attention. Three cooling systems are in use, the first and most common having a water reservoir surrounding the cylinder like a jacket; the second having a radiator and water-pump like an auto-

mobile motor; and the third being air-cooled. The water-cooled motors are most common and are most satisfactory for warm climates. The air-cooled motors have been on the market for a number of years and are successfully used by a few of the leading manufacturers. The ones with the circulating water system perhaps keep the engines at the most uniform temperature, and this system has been adopted on many of the latest-type motors. One of the second type is constructed so that the water-jacket around the cylinder forms the air-chamber for the pump.

The ignition system probably gives more trouble than any other part of the engine. Two systems are in use; magneto ignition and battery ignition, the former being the most popular, most expensive, latest, and least troublesome. However, when the magneto does occasionally go wrong, it usually takes an expert electrician to repair it. It is well to have a battery system in working order around the place if many sprayers are operated, so that in case of magneto trouble batteries can be attached while the magneto is being repaired. Battery systems get out of order through several causes, the most common being loose connections, weak batteries, mal-adjustment of vibrator spring, burning out or wetting of coils, and short-circuiting of the current. These can be traced down readily by one familiar with the system but it is hard for new operators to locate troubles of this kind. Guidebooks, which contain valuable suggestions for locating troubles, come with motors. The magneto ignition, being bolted directly on to the engine and having little or no exposed wiring, has far less chance of becoming deranged, and it is highly recommended for sprayer motors.

Governors are attached to many motors now to regulate the speed at which the engine runs. As the load is increased or decreased, the governor moves the throttle controlling the gasoline supply, enabling the engine to take up or drop the load and maintain an even speed. With such a control it is

not necessary for anyone to watch the engine, and every sprayer motor should be equipped with one.

Carburetors with only one adjustment—that of the needle-valve governing the gasoline flow—are to be preferred. A mark should be made on the carburetor to show the point at which the needle-valve control should rest in order to give best combustion. This should be tested occasionally as it is often necessary to change the adjustment for hotter or colder weather, or especially on a new engine to take up any changes which may occur after it is broken in.

Oiling systems are being simplified on newer motors, many having only one oiling point—the cup which drops oil in the crank-case. The splash or force-feed system oils all the other bearings on some of these motors. Simplicity in the oiling system means less likelihood of trouble, and is to be preferred. The oil-cup should be kept well filled, and an occasional inspection of the crank-case made to see that the oil is flowing in from the oil-cup fast enough to keep the oil up to the proper level. If oil runs in too fast the motor will smoke.

The engine may be placed either in front, in the rear, or on top of the tank. The advantage of a motor in front of the tank is that it puts the heavy load of spray material, when the tank is full, over the rear axle, and makes the outfit easier to handle. A disadvantage is that some teams are nervous when a gasoline engine is started immediately behind their heels and they have to be watched constantly. The disadvantage of a motor on top of the tank is that it is difficult to reach, interferes with the convenience of filling, and catches on branches in the orchard, often changing the engine adjustment.

QUALIFICATIONS FOR TANKS

Two types of tanks are in use, the wooden and metal. For the knapsack and compressed-air sprayers, the metal tank is exclusively adopted, while for the large sprayers with a tank capacity of 30 to 500 gallons, the wooden-stave tank is in

almost universal use. Most of them are U-shaped to permit the withdrawal of all of the materials and to eliminate corners in which sediment might collect. The agitator works most efficiently in a U-shaped tank. Tanks are mounted either on the ordinary wagon-bed above the axles, or they may be under-slung. The latter type of tank is especially desirable on hilly ground, as it minimizes the danger of capsizing. The under-slung tank may be filled more easily, as it is lower and the low frame necessary to carry an under-slung tank also permits the engine to be hung lower. The bed-sprayers have the tank mounted on top of the axle. These sprayers are ordinarily less expensive than the under-slung type and for work on level ground are just as efficient.

The size of the tank depends on the terrain over which the sprayer is to be hauled and the motive power to be used. While 200 gallons is the standard size at this writing, there is a tendency toward the use of larger tanks with 300- to 500-gallon capacities. When tractors or heavy teams are available and the ground level, not inclined to be too soft in spring or during wet spells, these are very desirable. For very hilly localities a 150- or even a 100-gallon tank may be necessary.

QUALIFICATIONS FOR TRUCKS

The truck is an important part of the sprayer. Steel frames are almost universally used and should be insisted on. Rocking bolsters are highly desirable as they allow the sprayer to travel over rough ground without racking the frame. Wheels vary in size from 28 inches up to as high as 54 inches. It is a distinct advantage to have the front wheels small enough so that the front axle can cut under the frame, thus making a short turn possible. This is especially desirable in closely planted orchards, such as peach or young apple orchards. If the ground is sandy or inclined to be muddy in the spring, it is desirable to have very wide tires on the wheels so as to give good traction. Five- to eight-inch tires are common on the

heaviest sprayers. On very large park sprayers flanges are occasionally placed on the wheels of the sprayer or truck. A tower is essential if very tall trees are to be sprayed. However, it is necessary only when the trees reach above twenty feet, as a spray-gun or spray-rod in the hands of an active thorough man will give a satisfactory coating up to that height.

QUALIFICATIONS FOR SPRAYING ACCESSORIES

Granted a desirable engine and pump, the sprayer may still have a very low efficiency unless the spraying accessories are of the type best suited to the work in hand. The height of the trees, the pests to be combated, the temperature and humidity of the day, the intelligence and ability of the labor employed, and many other factors determine the equipment to be used. For example, for high trees a tower may be essential on the sprayer. If a general coverage is desired for insects and diseases, spray-guns may suffice, while if the spray were being directed toward controlling leaf-hopper or pear-psylla on low trees, a rod with angle nozzles or an angle gun would be required. On hot humid days it may be dangerous to drive the spray through the trees with a spray-gun, when a fine mist drifted through the trees from spray-rods and nozzles would not cause any spray burning. Intelligent, capable operators might be trusted with spray-guns on days when less conscientious help should be given spray-rods with which to work.

Nozzles

There are three general types of nozzles: (1) The spray is broken up and given a flat fan-shaped form by striking an obstacle just outside the orifice. The bordeaux nozzle is typical of this group. (2) In this type the spray is broken up and given a cone-shaped form by the shape of the chamber within the nozzle. The Vermorel and disc-nozzles and spray-

gun typify this group. (3) The spray is passed through in a solid stream at great speed under high pressures and is broken up by resistance of the atmosphere after leaving the nozzle. The Worthley solid-stream nozzle used on park sprayers typifies this group.

The bordeaux nozzle consists of a movable brass cone inside of a brass cylinder. The cone has a hole bored through it to carry the spray material, and can be turned so that the hole directs the spray on to a beveled flange which flattens the spray out into a broad fan. The great advantage of the bordeaux nozzle is the driving quality of the spray. It may be used in considerable wind without much loss of efficiency. The chief disadvantage is that the spray particles are not fine enough and the ground cannot be covered as fast as with the cone-shaped spray from disc-nozzles. Another disadvantage is that the handle by which the angle of the cone is adjusted frequently catches in twigs. A third disadvantage is that the nozzle is heavier than most disc-nozzles. The bordeaux nozzle has an approximate capacity range of 1 to 2½ gallons a minute at 250 pounds pressure, depending on the size of the orifice.

The disc-nozzle (Fig. 21) is most common for orchard and garden spraying. The Vermorel was the first to come into prominence and has been in use since 1884. In 1906 a chambered disc-nozzle was constructed by the Goulds Manufacturing Company, Seneca Falls, New York, and has since largely replaced the Vermorel. It consists of two discs separated by a gasket from ⅛ inch to 3/16 inch thick, the outer disc having an orifice through which the material escapes, and the inner disc having two or more slanting entrances arranged around the outer edge through which the material enters the chamber

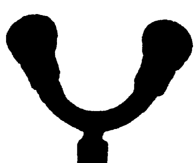


FIG. 21.—Angle disc-nozzles mounted on a "Y."

Those having four or six entrances have a greater drive to the spray, and have been found more satisfactory than nozzles with two or three when drive is desirable. The space between the two discs is called the eddy-chamber. The greater the depth of the eddy-chamber and the less the slant to the apertures in the inner disc, the longer and narrower will be the cone of spray, the coarser will be the drops, and the drive of the spray will be increased. Disc-nozzles are used for all types of spraying work except shade-tree spraying. They are especially valuable for row work in spraying field crops and for orchard spraying on still hot days when it is desirable to float a mist into the trees with little force. They have capacities ranging from ¾ to 1½ gallons a minute at 250 pounds pressure, depending on the size of the aperture in the disc and the type of construction. The mist produced is very fine, and the better ones will drive from 6 to 10 feet in still air.

It has been customary to arrange the disc-nozzles in pairs or in clusters of three or more for tree spraying. W. S. Hough of the Virginia Agricultural Experiment Station has shown that the drive is markedly affected by the arrangement of the cluster. The more the nozzles are bunched the greater is the drive to the spray, the narrower spread giving less air draft and longer distance. When three nozzles were placed in a row with centers 5 inches apart, the distance of effective drive of the spray was 11 feet, while when they were centered at 3½ inches the effective drive was 13 feet. A 1/16-inch orifice was used in the outer discs and 300 pounds pressure in these tests, and the flow was 3¾ gallons a minute. Four nozzles centered at 3½ inches, discharging 4¾ gallons a minute, gave a drive of 15 feet. Hough recommends this cluster over the ordinary spray-gun. When this cluster is placed on an 8- or 10-foot spray-rod the height reached by the fine mist is superior to that from a gun, and is even more effective when a wind is blowing. When sedimentary materials such as wettable sulfur are employed, the 1/16-inch aperture may clog

too frequently, necessitating the use of a 1/12- or 1/10-inch orifice.

The disadvantage of the disc-nozzle is that except in a cluster it cannot be used efficiently in spraying against the wind, nor can the range of the nozzle be changed as can the range of the bordeaux nozzle and the gun.

The Worthley solid stream nozzle consists of a long brass tube narrowing down toward the orifice to a comparatively small opening into which can be fastened jets or tips having a range of capacity of from 6 to 45 gallons a minute at 250 pounds pressure. When spraying tall trees the solid stream is broken up by air resistance into a fine mist, but when spraying smaller trees from 20 to 50 feet in height, a metal plate is attached, against which the solid stream strikes, a few inches beyond the end of the jet, spreading the spray into a fan, thus adapting in a measure the principle of the bordeaux nozzle.

Disc-nozzles are constructed to shoot a spray either straight ahead or at an angle, enabling the grower to spray in different directions merely by turning the rod. The angle nozzles are the more popular because they enable the operator to stand at one side of the drift when spraying in the wind and to coat more thoroughly the inside of the tree and under parts of the foliage. In mounting nozzles in a cluster, the cluster base may already have the 45-degree angle, in which case angle nozzles are unnecessary. If a wide spread is desired, the operator should use a straight cluster or Y and the angle nozzles. Some growers use clusters of three or four nozzles. Unless these are compactly arranged they are very heavy and cumbersome and are inclined to catch on the branches of trees.

Spray-guns (Figs. 22, 23)

The spray-gun is a large capacity disc-nozzle with an adjustable range. A movable plunger controlled by threads near the

handle enables the operator either entirely to close up the orifice in the outer disc or to draw far back from it. The farther the plunger is withdrawn, the narrower the cone becomes and the coarser are the particles, with a consequent greater drive to the spray. The great advantage of the gun is that the operator can instantaneously adjust the range and type of the spray, and he may coat foliage a few feet distant with a broad cone of fine mist or throw a narrow cone of coarse mist

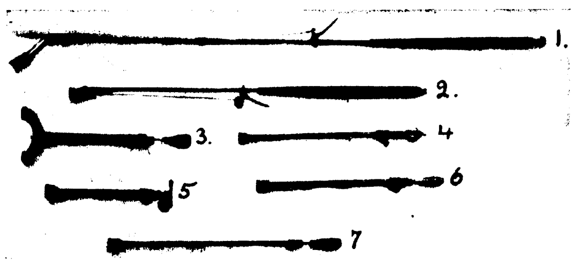


FIG. 22.—Some types of spray-guns. 1, Master pilot with angle-nozzle attachment; 2, Master pilot with straight-nozzle attachment; 3, Boyce; 4, Bean; 5, Friend; 6, Hardie; 7, Friend special.

into the top of a twenty-foot tree. Another advantage is the large capacity of the gun which enables the operator to cover a tree very rapidly. A third advantage is its lightness, as the average gun, 18 to 34 inches in length and weighing about $3\frac{1}{2}$ pounds, can be moved about with the motion of the wrist, while the spray-rod with the nozzles, Y, and cut-off weighs about double this amount and requires considerable physical exertion to move it about.

The chief disadvantage of a spray-gun is that it is a wasteful and dangerous implement in the hands of a careless operator, who tends to keep the nozzle well opened, with a consequent waste of spray and an increased danger of burning the foliage and fruit due to the driving of the coarse particles on

the foliage. When the gun is being used well open, it appears to the operator that the fine mist given off at the nozzle is being carried out to the utmost range of the spray, when in reality only comparatively few coarser drops are thrown farther than 10 or 12 feet. This leads to careless spraying in the upper reaches of the tree. Another disadvantage is that guns are frequently used on machines of too small capacity, resulting in low efficiency and consequently greater risk of poor control of insects and diseases.

Fig. 23.—The mist must carry to the top of the tree for effective spraying.

Another disadvantage of the spray-gun is that, due to its shortness, the operator is occasionally forced to stand in the drift of mist which occurs when even a mild wind is blowing. Operators, who in using a rod could remain perfectly dry, are oftentimes drenched when manipulating the gun. The final disadvantage is that particularly in case of large low spreading trees, the operator very seldom gets under the branches to coat the inner portions thoroughly with a spray-gun, while with a spray-rod with angle nozzles these less-exposed inner surfaces can be reached easily.

Most guns are constructed of brass, but the endeavor of manufacturers to reduce the weight has brought out the aluminum gun to which are attached the brass nozzle and working parts; thus lightness and durability are combined.

A modification of the ordinary spray-gun is seen in the Keith angle spray-gun and the pilot and master pilot rods, which are merely gun nozzles at the end of four or six-foot rods, a wire from the nozzle coming down to a controlling lever at the operator's hand, enabling him to adjust the flow of the spray. Many different manufacturers have put these on the market, but thus far none has been entirely successful, although the master pilot and the Keith gun, especially, have much to commend them.

Ample power and large capacity are essential to efficient operation of the spray-gun. A. L. Lovett, of the Oregon Agricultural College, and LeRoy Childs, of the Oregon Agricultural Experiment Station,[1] offer the following observations on the limitations in the use of the spray-gun:

"The spray-gun cannot be used effectively on a low capacity spray outfit. As a matter of fact, our modern 3½- and 4-horsepower machines do not possess sufficient capacity and reserve power to produce the ideal type of spray with two guns in operation. Those machines will produce a fair spray, but it is too coarse and there is not the driving power back of it necessary to do effective work in the tops of large trees. One gun may be used effectively, however, with the 3½- and 4-horsepower engine.

"In practice, we find that the average output of a 3½-horsepower outfit, operating two guns, is about four gallons a minute for each gun. This is average running time, including the shut-off in traveling from one tree to another. This means that when both guns are in full operation, the output is considerably higher, approaching, if not equaling, the output of the pumps. Spray machines of this horsepower have a rated pump capacity of from 8 to 10 gallons a minute. When both guns are operating, an examination of the overflow pipe indicates there

[1] Third Crop Pest and Horticultural Rept. Ore. Agr. Exp. Sta., 1915-20, p. 79.

is little or no fluid passing over. The pressure as indicated on the gauge may be high (250 pounds perhaps) and still there is not the 'life' that is observed in the spray that is thrown from a sprayer of 20 gallons a minute capacity with the pressure gauge reading approximately the same. A large overflow occurs on these high-capacity machines when two guns are being operated, and it appears that it is this added reserve, rather than the pressure indicated, which determines the quality of the spray. One gun on a good 3½-horsepower outfit throws a spray very similar to that from the larger machine. In this case, we have about one-half of the pump output passing through the overflow pipe.

"It has also been noted that less spray is used per minute on the large outfits than with the smaller machines. This is probably due to the fact that the material is more finely broken up. A surface can be covered just as quickly,—perhaps more quickly, with the fine particles than with a coarser spray. The result is that the gun is shut off more of the time and the average output per minute is reduced, resulting in a saving of spray.

"*Failures in the Use of the Spray Gun.* Poor results that have been obtained with the spray gun are not due to the principles involved in the spray application. Unsatisfactory control can be the result of the misuse of three, or perhaps, rather, the combination of three, misused factors. These are poor equipment, poor work, and irregularity of application. Of the three factors, the first mentioned is probably the most important from the standpoint of the use of the gun. The other two factors are contingent upon the first. The spray gun is a useless accessory to a poor spray outfit, and where operated with small, inferior equipment it has given a very poor account of itself and will never give good results. Our up-to-date 3½-horsepower sprayers are too small to handle two guns effectually. When equipped with one gun they function very satisfactorily. A machine of this power, in order to throw a spray of the proper quality, must maintain a pressure of at least 275 pounds. In one orchard under observation a machine of this character was used. In order to keep the spray in proper form the outfit was tuned up and pushed to the limit throughout the season. When you begin to force a gas engine and a pump, trouble begins, and the owner of this machine had his share. This condition of affairs existed in

many orchards throughout the (Hood River) valley and was typical of no particular make of sprayer. A spray machine, in order to last as long as it should and at the same time give results, must have a liberal reserve. A machine of 10 horsepower is none too powerful. Such spray machines are now coming into more general use and are winning favor."

Anderson and Roth[1] state that results of tests at Purdue and West Virginia Universities showed that:

"1. Disc nozzles in many designs tend to throw a spray in the form of a hollow cone having a heavy ring of spray with practically no material in the central area. Bordeaux nozzles give a more uniform distribution and the Vermorel the best of all.

"2. A common fault of many hollow-cone disc nozzles is their tendency to throw most of the spray in half of the circle.

"3. The smaller the angle of the spray holes leading into the eddy chamber, the wider is the angle of discharge, and the smaller the drops of spray.

"4. When the depth of the eddy chamber is increased, the size of the spray particles and the rate of discharge increase, but the angle of discharge and the width of the ring of spray decrease.

"5. A central spray hole in the eddy chamber makes the hollow cone of spray a solid one, narrows the angle of discharge and increases the size of the particles. A thick disc gives the same results and also decreases the discharge capacity of the nozzle. When the size of the outlet orifice is increased, the ring of spray is widened and the angle of discharge and amount of spray delivered are increased. Increasing the pressure produces the same results and also breaks the spray into finer particles.

"6. The amount of material delivered varies with the size of the disc opening and the pressure. Doubling the pressure does not double the amount of material delivered by the nozzle. The ratio of increase is 1 to 1.4.

"7. Doubling the diameter of the outer orifice increases the amount of material delivered about 3.5 times."

The thickness of the metal disc in which the orifice of the

[1] Anderson, O. G., and Roth, F. C., *Insecticides, Fungicides and Appliances.* John Wiley & Sons, Inc., 1923.

gun or nozzle is cut has a decided bearing on the distribution of the spray material. Many growers find that the thin discs wear out rapidly, so have thick discs made to overcome this. However, the angle of discharge of the nozzle is considerably reduced and the width of the ring of spray narrowed.

Rods

The spray-rod, while largely supplanted in commercial orchards by the spray-gun, is still an important accessory for the discriminating grower. Until about 1915 the bamboo spray-rod was the standard equipment. Some form of rod is required on every sprayer and it may vary from the 18-inch gun to the 12- and 14-foot extension rod.

Two types of extension rods are in use; the iron and the bamboo. The former is very durable but heavy, and inasmuch as the 1/4-inch pipe is the common size used, it is so small that it is difficult to grasp firmly with the hand. Bamboo rods are made of best-grade bamboo of as near even size from bottom to tip as possible, averaging approximately 1 inch to 1 1/4 inch in diameter and lined with a fine brass or aluminum pipe. They are much more practical and efficient than the iron extension rod.

The construction of the bamboo rod is important. Coupling clamps on the ends should be tight and preferably should permit of adjustment. If the clamp consists merely of a ring or strips of metal placed against the bamboo, a moderate amount of wear will loosen the clamp and the bamboo will turn without turning the lining. Bamboo should be selected which is clear of cracks and faults, and in case rough handling causes cracks to develop, the injured portions should be repaired immediately with adhesive tape.

The length of rod selected will depend on the use to which it is to be put. For average orchard conditions, a 10-foot rod is sufficient, but if one man must do all of the spraying and trees are high, it may be necessary to get a 12- or 14-foot rod.

For peach, sour-cherry, or small apple trees, a 6- or 8-foot bamboo rod is ample. Short rods are also used for spraying the under side of foliage in controlling leaf-hopper and aphis, and sometimes on the spray tower, because here the operator is handicapped by lack of room and a longer rod is sometimes objectionable.

A drip guard, to prevent spray material from running down the rod on to the hands of the operator is desirable. This consists merely of a metal or rubber collar which is screwed on to or stretched over the connection at the tip of the rod, and it turns all the drip aside. A wet rod is not only slippery and disagreeable to handle, but it causes considerable inconvenience by burning or blistering the operator's hands. A home-made leather guard which can be slipped over the end of the rod is also serviceable.

Cut-offs (Fig. 24)

An important accessory is the cut-off used both at the base of the rod and at the discharge pipe on the pump. Many different models are on the market, embodying special features such as quickness and ease of operation, completeness with which the liquid is shut off, lightness, and the like. All cut-offs should be made of brass or other non-corrosive materials and should be simple of design and easy to repack.

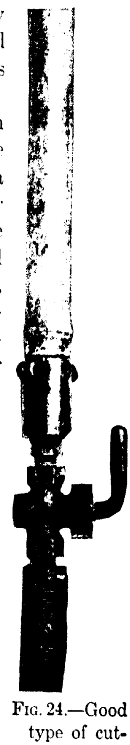


FIG. 24.—Good type of cut-off for rod.

A box cut-off is doubtless the simplest and most popular. It resembles a gas stop-cock except that it has a larger heavier handle. It turns off completely in a quarter turn. It is easy and rapid to operate and if kept well packed and oiled after use it lives up to its name, "leakless." In choosing this cut-off one with

a large handle which can be grasped by the hand should be insisted on. Ball-valve cut-offs of three types are on the market: one having a handle similar to the box cut-off and which can be closed or opened in a quarter turn; another having a control similar to a water-faucet requiring several revolutions for opening and closing; and a third having a handle with lever action. The second is a nuisance on a spray-rod because it takes several turns to close it, but it is satisfactory when used at the discharge pipe on the pump. The first and third types are efficient and positive in their action.

Special cut-offs have been designed for use on park sprayers where unusual pressures are encountered, but most of these are heavier than are desirable in orchard and garden spraying. In selecting any cut-off the points to be taken into consideration are simplicity of action, ease of operation, completeness of action, large straight waterways, and all-brass construction.

A cut-off enables the operator to shut off the flow of material when changing position. A larger amount of material than one imagines can be saved by constant use of the cut-off for this purpose. It enables the operator to remove the rod or nozzles to change or to clean them without stopping the engine. A cut-off on the discharge pipe at the pump enables the operator to repair or change hoses without stopping the engine or interfering with the other operator in case two lines of hose are used. At the discharge pipe it is better to have a Y and two cut-offs if two leads of hose are used, rather than one cut-off behind the Y, so that in case one lead of hose is out of commission the other operator will not be inconvenienced.

Hose couplings (Fig. 25)

The hose coupling has more potential possibilities for trouble than perhaps any other minor accessory used in spraying, as it is at this point that leaks are most likely to occur and

where hoses most frequently blow out. Requisites of a good hose coupling are as follows: (1) The coupling should be made of brass; (2) the shank on both male and female sections should be long, with at least two humps or ridges to offer resistance after the hose clamps have been tightened; (3) the waterway should be large, smooth, and unobstructed; (4) a grip for a wrench should be provided on both the male and female sections.

Many hand-sprayers, and an occasional power-sprayer, are sold equipped with hose on which are the shortshanked gar-

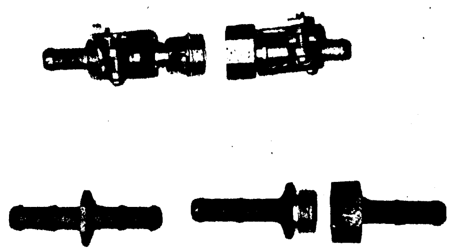


FIG. 25.—Desirable types of hose couplings.

den-hose couplings. These will not stand more than 100 pounds pressure and will blow out continually regardless of the kind of clamps used to hold them. Growers should insist on double-length shanks with all couplings. Some couplings have special sleeve clamps which lock into grooves at the base of the shank and which can be tightened by means of a heavy bolt and nut. These are desirable. The use of the simple couplings with brass hose clamps or wire will give satisfaction if they are properly applied in the first place.

Couplings for park sprayers have been designed which will hold hose under the highest pressures. In these, ease of

coupling and of uncoupling, and tightness have been combined, but they are heavier and more complicated than couplings used on orchard sprayers. One type, known commonly as the "quick-hitch coupling," is equipped with a rubber tube on the female half which slips into the male half, and the expansion due to pressure when the material is turned into the hose makes a tight and leak-proof connection. A heavy spring clamp on the female half slips over a shoulder on the male half to hold the two parts together.

Hose clamps

The most common form of hose clamp is the brass, iron, or aluminum ring which is drawn up by means of a stove bolt. Brass is the best material for these, as it resists weathering and the chemical action of sprays. Many patented clamps are on the market which grip the hose to the shank, but they are usually more expensive and often difficult to remove. Wire, while convenient, is frequently difficult to draw tight enough to withstand high pressures. For unusually high pressures encountered in spraying shade-trees, special hose clamps must be used, the principle by which most of them operate being that the greater the pressure exerted, the tighter the clamp is forced.

Spray hose

Hose is graded according to the number of canvas sheetings or plys used in construction, from 3- to 9-ply spray hose being common on the market at the present time. However, the quality of material in the construction varies so greatly that often the number of plys will not be a fair gauge of the quality of the hose, as some manufacturers use the best quality duck which makes a very durable hose, while others employ a less durable cheaper sheeting. There is no standard of construction at the present time for the spray-hose manufacturer, such as there is for steam or air-brake hose. Therefore, the grower

must use his judgment or his experience in making a selection. If a 5- to 9-ply hose made of high-grade duck and rubber is secured, it is well worth the extra premium which will be asked for it.

The size of the hose to use will depend on the volume of spray required to supply the nozzle. With a constant volume of spray flowing through a hose, friction increases as the size of the hose decreases. The area of the aperture in a 3/8-inch hose is 0.1104 square inches, while the area of a 1/4-inch hose is 0.0491 square inches. Therefore, the friction loss on the latter should be about double that in the former. The losses increase as the volume passing through the hose is increased. W. S. Hough, of the Virginia Agricultural Experiment Station, using exactly similar nozzle clusters at 300 pounds pressure at the same time on the same machine, but with hoses of different size, obtained the following results due to loss of pressure:

Hose Used	Gals. a Minute Delivered	Distance of Effective Drive of Spray
5/8-inch, fifty feet	5	15 feet
1/2-inch, fifty feet	4 7/8	15 feet
3/8-inch, fifty feet	4 3/8	12 feet

The Bean Spray Pump Company found the following friction losses in 50-foot lengths of hose when 300 pounds pressure was used at the pump and nozzles discharging various volumes of fluid:

Gals. a Min. Delivered by Nozzle	Pressures Recorded at Nozzle		
	3/8 in. Hose	7/16 in. Hose	9/16 in. Hose
2 1/4	295 lbs.	300 lbs.	300 lbs.
3 3/4	275 lbs.	295 lbs.	300 lbs.
5 1/4	235 lbs.	285 lbs.	295 lbs.
8 1/2	200 lbs.	265 lbs.	280 lbs.
11	160 lbs.	240 lbs.	260 lbs.

Three-eighth-inch and 1/2-inch hose are the two common sizes in orchard work. The latter should be used if a nozzle

discharging more than 4 gallons a minute is employed. F. C. Sears,[1] of Massachusetts Agricultural College, shows the weights of hose of different sizes by the following table:

COMPARISON OF WEIGHTS OF HOSE OF DIFFERENT SIZES

Length Feet	Size Inches	Kind of Hose	Weight, Empty Pounds	Weight, Full Pounds
25	3/4	Rubber	10.87	13.56
25	1/2	Rubber	6.66	9.16
25	1/4	Rubber	4.11	4.45
25	3/16	Special cloth-covered	1.00	1.75

It has been the observation of many growers that very heavy hose, such as ¾- and 1-inch, wear more rapidly from being dragged about, due to greater weight and consequent greater friction, than do the ⅜-inch and ½-inch hose. The writer used two 50-foot leads of 9-ply ½-inch spray hose for four years in spraying 65 acres of mature apple trees from four to six times a year, all the spraying being done from the ground with the hose dragging, without hose trouble.

Soft rubber hose put on the market has not stood up under use satisfactorily. They kink badly and wear out easily when dragged on gravelly soils.

The length of hose to be used in spraying depends on the type of work to be done. For ordinary orchard spraying not less than 35 feet should be available, while 50 or 60 feet is better, especially if the trees are mature. A smart operator soon learns to allow the team to drag the hose, really carrying very little of the weight himself, yet he has the latitude and freedom which goes with the use of a long length of hose. Short lengths of hose lead to inefficient spraying, the far sides of the trees being especially subject to neglect, as a little movement on the part of the team disturbs the operator and entails skipping portions of the tree. Fifty feet of hose is a

[1] Sears, F. C., *Productive Orcharding.* J. B. Lippincott Co. 1914.

good average length for all types of orchard spraying. For park sprayers, where hose as long as 2,000 or 3,000 feet is occasionally required, special types and grades must be purchased. Hose of ½-inch capacity is used for the first 1,000 or 2,000 feet behind the nozzle. As longer hose is required, additional sections of ¾-inch and finally 1-inch are added, the smaller hose always being toward the extremity. To develop 200 to 250 pounds pressure at the nozzle through 3,000 feet of hose, from 400 to 600 pounds pressure must be developed at the machine. Where 5,000 or 6,000 feet of hose are required to spray distant trees, as has been necessary in some recent gipsy-moth control work, sometimes 1,000 pounds pressure is necessitated at the machine and 2,000 feet each of ½-inch, ¾-inch, and 1-inch hose must be used. Especially high pressures are required when the hose runs uphill, as it takes considerable pressure to lift the water to the summit of the hill before any pressure is exerted on the nozzle.

The life of the hose depends largely on the care it receives. Rubber depreciates very rapidly when coated with oil or corrosive spray materials. Dragging the hose, allowing kinks to form, and undue strains are injurious as they fracture the fabric and cause blowouts or leaks. Hose should never be coiled and hung on nails as this places all the strain at one point and causes the fabric to fracture. A small keg nailed to the wall makes an excellent hose rack. A fifty-foot gently sloping shelf, if such is available in a cool damp storehouse or cellar, makes the ideal storage.

Hose should either be disconnected and allowed to lie in the orchard while the machine is refilled, or looped over hangers on the rear or coiled on top of the sprayer.

At the conclusion of each day's work the suction hose for the pump should be thrown into a bucket of clean water and the pump and the hose thoroughly washed out until clear water runs out of the nozzles.

Spray booms (Fig. 26)

For spraying field and row crops many booms have been designed which carry a large number of nozzles. On a large capacity sprayer as many as six rows of potatoes or tomatoes can be sprayed, using as high as eighteen nozzles, but the size of the orifice in each nozzle necessarily must be small. A boom consists of a pipe running horizontally across the rear

Fig. 26.—Spraying cranberries. The spray rig remains on the bank of the bog. Long leads of hose are carried and the material is applied by nozzles on booms, as above, or by spray-guns.

of the sprayer. It is coupled to the discharge pipe by a hose. At intervals, depending on the width of the rows and the arrangement of the nozzles desired, quarter-inch pipes or hose drop down, to which are attached the nozzles which do the spraying. Three nozzles are customarily directed at each row of such crops as potatoes or tomatoes, one playing directly on top of the plants, while the other two are carried close to the ground and are tilted slightly forward and upward to coat the under sides of the leaves. Both angle and straight nozzles are

required for this work. For grape spraying one vertical boom is fastened on each side of the sprayer and from two to four nozzles are distributed along each boom. The operator merely starts the engine, turns on the spray, and drives down the row to coat the vines.

Disc-nozzles are used almost universally on spray booms while ½- or ¾-inch pipe is customarily employed in making the frame of the boom, and ¼-inch pipe or hose for the short leads which carry the nozzles. An all-metal boom has very little flexibility and is likely to be injured in turning at the end of rows or by being caught on posts and trees. Therefore, booms are frequently made in which short lengths of rubber hose are fastened, so that in case of an accident the boom will not be broken. Often a small piece of hose is used on the tips carrying the nozzles, so that in case a rock or stump is struck the pipe will not be broken off. On level well-cleared fields these precautions are not as essential. An excellent flexible type of vegetable spray boom has been designed by C. H. Nissley, of the New Jersey Agricultural Experiment Station. This boom was designed especially for directing the spray to the under sides of the leaves, and embodies the following features:

The drop nozzle is attached to the ¼-inch drop pipe, which is connected to the cross member by means of a hinge joint. An adjustable shoe is fastened on the lower part of the drop rod, allowing the nozzle to be set at will from 1 to 9 inches from the ground. At all times the position of the nozzle in relation to the plant being sprayed is the same, as the nozzle always remains in the same relative position regardless of the contour of the land. The shoe trailing on the ground keeps the nozzle up from the ground and as low down as desired. The shoe also allows the drop member to ride over any obstruction in its path without being broken.

CHAPTER VIII

THE CENTRAL STATIONARY SPRAY PLANT

SPRAYING equipment of this kind has been in use for almost twenty years in the far West, and has become particularly favored there since 1920. The plan is simple, consisting of a pumping plant set up at a favorable point in the orchard, and a network of pipes to carry the spray material under pressure through the rows. Outlet valves are set at intervals throughout the system, from each of which fifteen to thirty or forty trees may be sprayed with a hose 75 to 150 feet in length. (See Fig. 27.)

The plan has been tried sufficiently to insure practicability. Growers using it are strong in their commendation. It is in operation in districts where sedimentary materials, such as self-boiled lime-sulfur, are used and no clogging of the pipes has been experienced. The original cost of the equipment and installation on large acreages is about the same as for portable equipment, but spraying costs are markedly cut thereafter. On small blocks the cost of equipment and installation is somewhat higher to the acre. In localities where there is a labor shortage during spraying season this system has particular advantages. It is of greatest advantage when it eliminates horses and tractors altogether. When this motive power is needed on the farm anyway, it may be cheaper to use portable outfits than to allow teams to stand idle.

Some of the advantages of this system are: (1) It increases the acreage which can be covered with a given crew of men 25 to 50 percent; (2) eliminates the waste of time driving to and from the filling station with portable outfits; (3) frees

FIG. 27.—A Ford engine and frame serve as power unit and mount for pump in this stationary spray plant.

horses, tractors, and labor to drive them, for other farm work; (4) enables spraying when the ground is too soft for portable sprayers or when trees are so bent under loads of fruit as to prevent driving through with a sprayer; (5) concentrates the mixing, filling, and pumping operations at one point; (6) saves wear and tear on the pumping machinery in hauling over rough ground; (7) enables cheap and efficient spraying in orchards situated on steep land where portable rigs are used with difficulty.

Installation of stationary systems does not mean that all the old equipment must be scrapped. The engines, pumps, hoses, guns,—in fact everything but the old trucks,—frequently may be used in the stationary outfit, particularly when several old machines can be operated in batteries to give the required volume and pressure.

The piping is quite permanent when taken care of. Systems have been in operation for over fifteen years without trouble with the pipes. Galvanized iron, wrought iron, and black iron or steel pipe are in use, the former being the most popular. Wrought iron pipe is not employed much because of the expense. The black iron or steel pipe is the least expensive and least durable of the three.

Two systems of arranging the piping are in use: the "dead end," in which a main supply pipe is laid, from which are taken off laterals with blind ends; and the circulating system, in which these laterals are connected with a return pipe so that the material circulates through the system. The latter method may be preferable in orchards in which self-boiled lime-sulfur, wettable sulfurs, or other sedimentary sprays are used. These materials might settle in and clog the laterals in the "dead end" system, but are kept in suspension by the rapidly moving current in the circulating type. The latter is a little more expensive to install. (Fig. 28.)

There are three methods of laying the pipes through the orchard: On the surface, buried 10 to 20 inches underground,

or strung overhead. When the pipes are laid on the surface they are somewhat in the way of other orchard operations, particularly if the orchard is cultivated. Some growers disconnect the pipes in 100- to 200-foot lengths and drag them

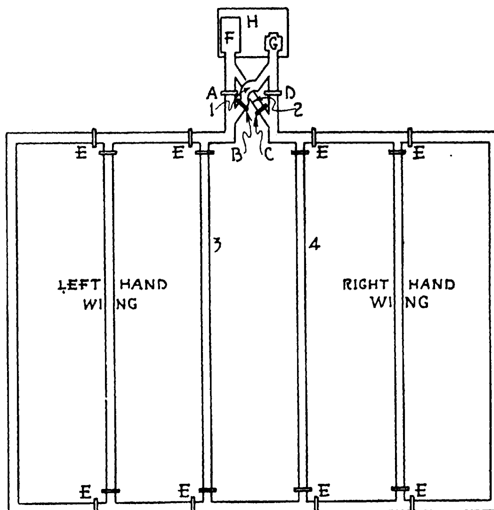


FIG. 28.—Detail of return spray installation. A, B, C, D, E, gate valves; F, pump; G, overflow discharge through regulator or relief valve into tank; H, pump house. When spraying right-hand wing, lateral 3 will be return overflow line, and when spraying left-hand wing, lateral 4 will be return overflow line. To reverse system for right-hand wing of field, close valves A and D and open valves B and C, making line 2 the discharge line and line 3 the return overflow line.

to a convenient storage point after the spraying season is over, while others allow them to remain out all season.

If the pipes are to be buried they are usually laid just deep enough to be out of the way of cultivation equipment. If the

pipes are only 10 or 12 inches deep it is easy to take them up in case of leaks or trouble. Ditches for the pipes are usually opened by plowing one furrow inside of another. Some hand digging is essential in many places, but the plow saves much labor. Drain plugs must be installed at all low points in the system so that the materials may be run from the pipes in winter. Some poor grades of oil emulsion will "break" if allowed to stand over night in the pipes.

The relative merits of the overhead, surface, and underground systems of laying pipe are debatable. In the West some of the growers who have laid pipes underground have found it too hard to locate troubles, and are digging them up and placing them on the surface. When ground is sandy, perhaps the ease of digging would eliminate this difficulty. O. M. Morris reported that more growers are swinging over to the overhead system. At present it appears as if the surface system is the most popular.

No factor is more important than the size of pipes. Friction is high in small pipes, particularly when a large flow of material is required. Capacity of a pipe increases very rapidly with increased diameter, and friction falls proportionately. On the other hand, if pipes of too great diameter are employed the sluggish movement of the spray solution will allow lead arsenate and other sedimentary materials to settle.

The size of the main line will depend on the volume of the spray flowing through it. Experience has indicated that main lines of 1¼-inch pipe, with ¾-inch laterals not to exceed 500 or 600 feet in length are satisfactory when two guns on the whole system are used. When not more than one nozzle is employed on a lateral at one time, pipe of ¾-inch size may be extended to 800 or even 1,000 feet without difficulty. The length of the pipe, the gallons a minute flowing through it, and differences in elevation between ends determine the loss in pressure in the pipe. The Engineering Handbook gives the following data showing loss of pressure in pounds to a square

inch due to friction, of water delivered through 100 feet of standard steel or wrought iron pipe.

Gallons a Minute	Inside Diameter of the Pipe				
	½ in.	¾ in.	1 in.	1¼ in.	1½ in.
4 gals. a minute	6.0	1.4	0.4	0.12	......
5 gals. a minute	9.0	2.25	0.64	0.17	......
6 gals. a minute	12.5	3.15	0.95	0.27	......
8 gals. a minute	21.0	5.5	1.7	0.44	......
10 gals. a minute	32.0	8.0	2.5	0.65	......
15 gals. a minute	......	18.0	5.5	1.5	0.7
20 gals. a minute	......	32.0	10.0	3.0	1.2

It is readily seen from the table that when two guns are used on one lateral, a ¾-inch pipe is essential unless excessive losses of pressure are experienced. This is borne out by inspections of systems already installed.

Each foot rise of elevation decreases pressure 0.4 pounds, while each foot drop in elevation increases pressure 0.4 pounds. Each tee or elbow equals in friction about 40 feet of straight pipe.

The size of pipe will, therefore, depend on the conditions in the individual orchard. If only short laterals are needed and only 5 gallons a minute required, half-inch pipe might be used with entire satisfaction. Cost of installation may dictate the use of small pipe in some cases, but the facts should be considered carefully before such equipment is decided on.

Unless differences in elevation in the orchard dictate the location of the main line, the center is the proper place for it, as then the laterals are of the shortest possible length. If it is necessary to place the main line along one side it should be between the second and third, or third and fourth rows so that outlets placed at the junction of each lateral will enable the spraying of the first few rows. Where differences of elevation are not significant and distances are not great, placing the main line along the low level of the orchard will permit

draining all material back into the main and thence back into the tank at the conclusion of each day's spraying.

The distance between laterals will depend upon the planting plan of the orchard. The tendency is to place them at such intervals that about 100 feet of hose will suffice. This enables one man to handle both hose and nozzle, while if longer hose are required each operator will need a helper to drag hose. If the trees are 30 x 30 feet apart, on the square system, a lateral in the center of every fifth row (150 feet apart), an outlet every 90 feet along the lateral, and 87 feet of hose will enable the operator to spray fifteen trees from each coupling (Fig. 29). If the trees were 40 x 40 feet apart, the laterals would be 200 feet apart, the outlets every 120 feet along the latter, and it would require about 115 feet of hose to spray fifteen trees. The grower can easily tell with a measured piece of stout cord in the orchard the proper distances for laterals and outlets, and the lengths of hose required for his particular case. The system coming into great popularity in the West is to place the laterals at every seventh row, with outlets at every other row. Two rows are sprayed at one time. While only fourteen trees are done at one coupling, the labor saved in dragging the hose results in speedier spraying (Fig. 30).

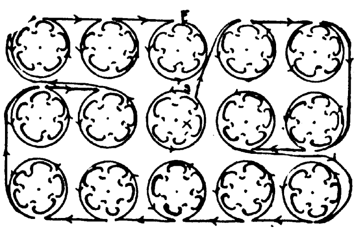


FIG. 29.—Method of covering fifteen trees from one hydrant by means of stationary spray-plant system. Attach hose and start at S, follow arrows, and finish at F.

A gate is placed in the lateral at the junction with the main line. Some install a gate in the main line just beyond the take-off of the lateral or of every two or three laterals, so that only the part of the system actually in use is filled with

spray. It takes a large amount of material to fill the piping system. One hundred feet of ¾-inch pipe will hold 2.3 gallons, while the same length of 1¼-inch pipe will hold 6.38 gallons. In addition, if the spray material stands in the pipes they depreciate faster than do clean pipes and there is less likeli-

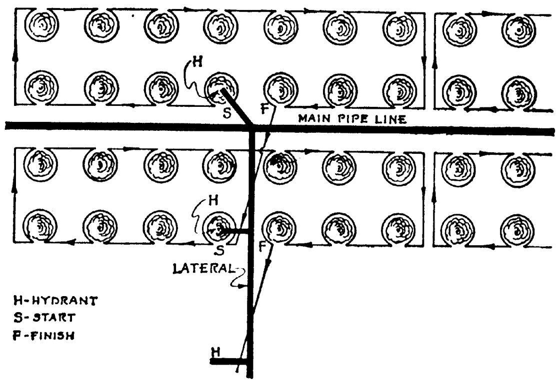


Fig. 30.—Method of spraying two rows or fourteen trees from each hydrant.

hood of clogging with sediment if the laterals are only opened when in use.

The lines are laid between the rows when the pipes are buried, so as not to interfere with the roots. At intervals a short stub is extended to a tree-trunk where a riser and outlet valve are located. Hydrants thus placed are in no danger of being broken or bent. When the pipes are left on the surface they are usually laid along the line of tree-trunks, and the outlets placed as above. When the overhead system is used, the pipes are placed through the trees, usually about 8 feet above the ground, being supported by crotches in the branches and reinforced by poles when necessary. At proper intervals an 18-inch drop-line and hydrant are placed. With the over-

head system in use it is much easier to drag the hose, as it can be lifted off the ground by pulling against the hydrant.

The central pumping plant is best located at the water supply. If this is above the level of the orchard there is a gain in pressure in the pipes due to gravity and the burden on the engine and pumps will be correspondingly lighter. This is especially true when there are large differences in elevation in the orchard. In West Virginia there are orchards in which a pressure of from 200 to 500 pounds is necessary at the pump situated at the lower level before the liquid will even run out of the hydrants at the top, and 600 to 800 pounds working pressure is required.

It is difficult to lay down rules as to the size of equipment to install, as each orchard is an individual problem. Growers have found that an engine and pump will supply more material at higher pressures in a stationary system than when used as a portable outfit, particularly when it is located above the orchard level. These gains are usually not of sufficient importance to warrant the installation of light equipment. When two guns will be operated, an outfit capable of delivering 12 to 15 gallons a minute at the required pressure should be installed. The principles discussed in the preceding chapter should be kept in mind. When material must be raised several hundred feet it will require a special pump capable of developing 500 to 1,000 pounds pressure. Most spray machinery manufacturers are making special high-duty equipment for stationary work.

Usually there will be a supply of old portable machines to be worn out. In some places these have been installed in the pump-house so that one or all of them can be operated as need for volume dictates. The advantage of having two or more small units in place of one large one is that in case of a breakdown of one, the others can carry most of the load alone. Old automobile engines are occasionally used to supply power to

a shaft to which several pumps can be connected through clutches. The help of a mechanical expert should be obtained in setting up such equipment. An electric motor is very satisfactory if there is sufficient work to warrant the installation

FIG. 31.—A helper is needed to drag the hose, if more than 100 feet is used in one lead.

of such equipment. Tractor power may also be employed efficiently.

Large mixing tanks are the rule, 500 to 1,000 gallon U-shaped concrete or wooden tanks being employed. Best agitation can be secured in a tank of that shape, while rectangular vats have corners in which material may settle. Wooden tanks are least expensive, and are easy to move if necessary. Concrete tanks are durable and easy to build. On large acreages two

tanks are employed so that one can be filled while the other is in use. Thus spraying proceeds without interruption.

When only a few acres are involved, the operator and perhaps his helper must do all the work and there is little chance for division of labor. In extensive orchards where several guns are operated simultaneously, one man mixes the material and

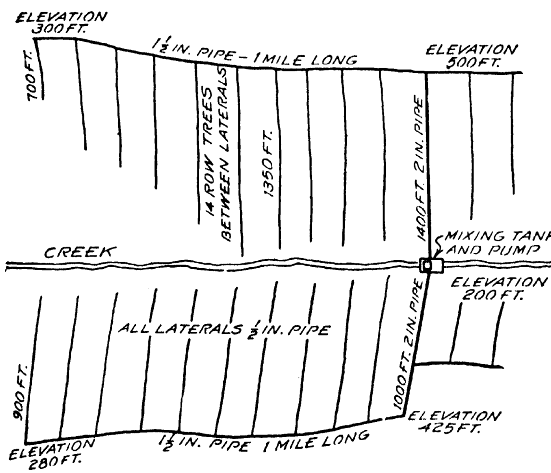


FIG. 32.—Layout of pipe system in the Chert Mountain Orchard.

runs the engine and pumps so that the spraying crews are never idle. When laterals are not more than 150 feet apart, so that 100-foot hose lengths can be used, one man handles each hose and does the spraying. Attaching the hose to the operator's belt facilitates dragging, and frees his arms for spraying. When laterals are farther apart, requiring 150 to 250 feet of hose, each sprayer must have a helper to drag each 100 feet of ½-inch hose, as the ½-inch hose filled with spray will weigh about 40 pounds to each 100 feet. (Fig. 31.) When

several crews are at work there should be an overseer to check up on the work, to look for troubles, repair leaks, and help out where most needed.

There is considerable variation in the expense of setting up a stationary spray plant. O. M. Morris[1] cites instances in orchards of 4 to 15 acres where the entire cost including pipe, valves, engines, pumps, tanks, and installation ranged from $60.00 to $100.00 an acre. Charles Repp laid a circulating system on 100 acres in Glassboro, New Jersey, in 1927 for $32.00 an acre including all labor, equipment and materials. The cost of installing the outfit in the 300-acre Chert Mountain Orchards, Rada, West Virginia, shown in Fig. 32, was about $13.00 an acre. As Morris points out, on small orchards where only two or three applications of spray are given annually, the cost of the stationary spray plant would probably be prohibitive. In large orchards it is very comparable to the cost of buying and maintaining portable outfits. A $600 sprayer will cover about 30 acres of mature trees, while a $250 team or $500 tractor, a considerable part of which must be charged to spraying, is needed to pull it. Thus the cost to the acre is in the neighborhood of $30. This amount will install an excellent stationary spray plant, with the prospect of a longer life, and considerably lessened operating costs.

[1] Morris, O. M., Wash. State Agr. Exp. Sta. Pop. Bull. 125. 1924.

CHAPTER IX

THE ART OF SPRAYING

GOOD judgment must be exercised in the selection of the equipment, materials, and the manning of the machinery. This cannot be acquired in a day and rules cannot be laid down which will cover every case. Here the personal factor enters deeply.

This is especially true in the spraying of tree-fruits where much labor is required and where there is far greater danger of damage being done if the best judgment is not exercised. Materials satisfactory for certain kinds of fruits are too caustic for others; nay, the line must be drawn even more finely than that—in some sections standard materials like concentrated lime-sulfur can be used as a summer spray on varieties of apples like Rhode Island Greening, Delicious, McIntosh, and Wealthy in humid weather, yet cannot be employed on Williams, Jonathan, Duchess, Gano, and Ben Davis without danger of severe burning; on these varieties less caustic sprays must be used. Even on the varieties more resistant to burning, damage may be done when combinations of high temperature and humidity are met with. The keen grower knows when to change his practices.

There are many niceties in organizing the spraying work which will be taken advantage of, particularly by the thoughtful experienced orchardist. The arrangement of the supplies at the filling station and the laying out of the spraying procedure, aid in saving of labor and materials. In spraying field crops the machines deliver a certain amount of spray through set nozzles which are not altered by the operator after

they are once adjusted. This, coupled with the regularity of the rows and the comparative immunity of the plants from spray injury, makes it a much less exacting piece of work than the spraying of tree-fruits. In the latter, the man is the important factor, while in the former the spray boom does the work, provided the driver uses reasonable judgment in directing the team.

The secret of effective spraying lies in the observance of several fundamentals, such as timeliness of application of protective coatings, thoroughness, and use of proper equipment and accessories. With these are associated factors such as methods of approach to the tree, utilization of labor, the arrangement of the supplies of water and materials, the manning of the spray machine, and the like. It is difficult to lay down hard and fast rules for these because individual cases differ widely. Perhaps it is because these individual differences require the personal factor for their solution that spraying is an art.

TIMELINESS

Insects and diseases come and go with more or less seasonal regularity, and in a general way the grower may at least know what to expect. Some of the pests can be controlled by applications at any time over a long period of the year. San José scale and peach leaf-curl are examples of these. The control of most pests, however, such as apple-scab, codlin-moth, potato-aphis, and currant-worms, is an operation requiring exact timing.

Fundamental reasons underlie the need of this careful timing. One is that there are certain weak spots in the seasonal life history of the pest, enabling the grower to attack it with better chance of success. Another is that there are certain short critical stages in the seasonal life history of the host when the protective sprays can best be placed.

Apple-scab is an example of a pest having a short vulner-

able period in its development. That period is the spore stage. If scab infection develops past this point, spraying is ineffective. During the early spring the over-wintering bodies, which carry the scab organism from one season to another, have been ripening and preparing to discharge millions of microscopic spores into the air at a certain favorable moment. When rainfall has softened the covering of the ripe over-wintering body, it bursts, and the same rainfall has made conditions favorable for quick germination of the spores after they alight on the apple foliage or fruit. These spores may be killed or their germination inhibited by fungicides such as sulfur or copper sprays. The spray must actually be on the plant when the spore arrives there, or if the weather is dry it must be applied before the arrival of the next rain to be effective. In the early spring growth of the apple tree is very rapid, sometimes a 75 per cent increase in leaf surface taking place in ten days at about blossom time. It would take constant spraying to keep this new foliage covered. This is impractical. Therefore spray applications must be made just before rainy spells in order to control apple-scab. A week before is too long. The grower must be able to coat his trees in three or four days. Weather reports must be watched carefully and perhaps some of the orchard dusted if the schedule cannot be maintained with liquid sprays, because the spore stage is the critical period in the control of apple-scab.

Aphids of all kinds are most easily controlled immediately after hatching. Contact with them at that time is not difficult, because they have not had time to roll or curl the leaves. If a thorough eradication of the so-called "stem mothers" can be effected, no further trouble will be experienced from that brood.

The spring and fall canker-worms appear on apple foliage shortly after the leaves unfold in the spring, coming out almost over night. If arsenicals are not already on the foliage and

application is delayed for a few days, the insects grow larger, are harder to kill, and do a great amount of damage.

A classic example of the short critical stages in the seasonal development of the host plant, during which pests may best be controlled, is seen in the application of the petal-fall or calyx spray for the control of the codlin-moth on the apple and pear. When the first worms appear a month later, large numbers of them enter the fruit through the blossom-end, feeding first in the calyx-cup, and to kill these the latter must be filled with spray. However, the calyx-cup is only open for a few days at blossom time, and therefore the control of this pest depends first of all on the exact timing of the spray. If it is delayed even five or six days after petal-fall in some warm seasons, the calyx closes and thereafter effective control is impossible (Figs. 33, 34).

FIG. 33.—The two apples on the right have "set" and the calyx-cups are closing. The one on the left is not going to set, and the calyx remains open. Spraying for codlin-moth must be timed to strike the advanced, or developing blossoms.

Several factors contribute to timely spraying. The first of these is to start slightly ahead of, or at least very promptly on, schedule if large acreages are to be covered. State experiment stations publish detailed schedules describing the times

to put on sprays, and in many cases a notification service is maintained by government agencies, cards or telephone messages being sent out so as to reach the growers at least two or three days in advance of the time when the spray is due. In case there is no notification service, growers must keep in close touch with the Weather Bureau, and judge their own

FIG. 34.—Calyx-cup closed. It is too late to apply the calyx spray for codlin-moth.

conditions. On Saturday or Sunday the papers usually give the long-range forecasts, and while these will not supply the information on the condition of the insects, still they will enable the grower to tell whether growth is going to be advanced or retarded, and the weather warm or cold, rainy or dry.

It is generally possible to start applications slightly ahead of time, so as to allow ample opportunity to cover the entire

acreage even though a few days are lost through inclement weather. The pink-bud spray may be started when the scab spores are about ripe, or, lacking this information, as soon as the central bud of the cluster shows full pink. The petal-fall spray can be started when the blossoms are three-fourths off, which allows in normal seasons seven to ten full days for the application. Other sprays on which advance information can be secured by observation can be started slightly ahead of time.

The second factor which will contribute to timely spraying is the maintenance of ample equipment necessary to cover the acreage at hand. Various estimates have been made by investigators and practical orchardists as to the number of acres one machine can safely be expected to cover, and these figures vary from twenty to forty acres. No definite rule can be laid down. Most commentators agree that given a reasonably available water supply and other conditions, it is not safe to figure on more than 2,000 trees of medium size requiring five gallons a tree, to every spray machine, team, and three men. The 2,000 trees would require 10,000 gallons of spray, and at the rate of 1,800 to 2,200 gallons a day such an orchard could be covered in five to six working days.

A third way of assuring timeliness of application is by having auxiliary equipment, such as a dusting machine (Fig. 35), to fall back on in case the spraying gets behind. Three or four acres of orchard may easily be dusted while one acre is being sprayed, and dusting is perfected to such a degree that growers may rely on it for emergency work, while many are using it altogether for their summer sprays on apples and peaches with entire success.

A fourth safeguard to timeliness is the maintenance of a well-equipped fully stocked repair and supply room. The up-to-date grower, who is operating several spray machines, maintains a modern repair shop in which there is an experienced mechanic and a stock room in which is kept a full

supply of parts likely to be needed in making ordinary repairs. The equipment of such a supply room is taken up in another section. (See page 196.)

THOROUGHNESS

Thoroughness in the art of spraying means more than the mere careful application of materials. It starts with the kind

FIG. 35.—The dusting machine, with which forty or fifty acres can be covered in one day, is a valuable adjunct to the spray equipment in case the spraying work gets behind.

of spray schedule adopted, and, in fact, can be said to go back even to orchard sanitation and preparation of the trees for spraying by careful pruning. It extends all the way down to the actions of the individual operator who directs the nozzle.

The first factor contributing to thoroughness is proper pruning. The most careful operator will not control such diseases as scab, bitter-rot or blotch, and will not prevail against curculio,

aphis, and similar insects, if the trees are so thick and brushy that the materials cannot penetrate the inner portions of the tree. At least, with such brushy trees, coverage is almost sure to be less complete and the results less satisfactory. Therefore, a very desirable preliminary to spraying is the careful pruning of the orchard. The dense head should be well opened up and clusters of small twigs toward the end of the branches pruned out, so that even with the weight of the fruit and foliage the limbs will not mat down on one another and prevent a thorough coating of spray being given. High tops, beyond the reach of the tower and spray-rod, bear quantities of defective fruit, and should be headed back within reach of the usual nozzles. Le Roy Childs, of the Oregon Agricultural Experiment Station, showed by some experiments in spraying with guns that only 1.46 per cent of the fruit picked below a height of 12 feet was wormy, while 3.6 per cent of the fruit between 12 and 22 feet was wormy, and 17.8 per cent of the fruit from 22 to 28 feet was wormy. Very low branches should be sufficiently thinned out to permit the operator to walk under large trees, so that the inner portions can be coated thoroughly.

Second, orchard sanitation measures have a considerable bearing on the reduction of insect and fungous injuries. Banding of trees in districts in which codlin-moth is serious is an effective method of reducing the number, and is an important adjunct to spraying for this insect. Bands must be visited every week or ten days during the summer to remove the larvæ. Burning of hedgerows to kill the curculio and the cutting out of cankers which carry over apple-blotch, bitter-rot, and the like, are indirect operations which, like pruning, contribute to thoroughness of application of sprays.

Third, the application of the spray coating is the greatest direct factor in thoroughness (Fig. 36). The responsibility for this operation lies in the hands of the crew on the spraying machine. The grower who can apply his own spray material or, at least, be constantly in the orchard during the spray-

FIG. 36.—Worms attack fruit in sheltered spots, as where two apples hang together, and thorough spraying is required to coat these protected places.

ing season to observe the methods, may expect the cleanest fruit at harvest time. Thoroughness does not require drenching, but it does require spraying from all angles so that both *upper and lower surfaces of leaves, twigs, and fruit are covered.* Special attention must be given to the spraying of the upper parts of the tree. Especially with a spray-gun, the operator is likely to assume that a mist has been thrown into

FIG. 37.—Spray boom of excellent type, showing arrangement of nozzles to insure thorough covering of the vines.

these more distant reaches because of the amount of mist which blows off the nozzle close to the ground, when in reality only a comparatively small amount of coarser drops are reaching the top of the tree.

Fourth, maintenance of the coat is the next factor in thoroughness. In most well-developed orchard districts, such insects as codlin-moth and such diseases as apple-scab and

brown-rot occur more or less constantly throughout the season, and if the grower relies too implicitly on a spray schedule which does not take into consideration rain-storms which may wash off the coating, insects and diseases may attack his trees and cause great loss.

Fifth, thoroughness will depend somewhat on the amount of spray used to each tree. No grower who is parsimonious of his materials deserves good results.

In Oregon it was found[1] that trees of various ages required the following amounts of spray:

Age of Trees	*No. of Sprays*	*Total Gals. per Tree*	*Average Gals. per Tree per Spray*
8 years	7	30.7	4.39
13 years	8	38.4	4.8
14 years	7	36.9	5.27
16 years	8	48.7	6.08

Sixth, the last factor in thoroughness of spraying is the selection of good equipment (Figs. 37, 38). The use of towers when high trees are sprayed makes it possible better to protect the upper reaches of the high trees.

EQUIPMENT AND ACCESSORIES

The average grower will in practice usually have one spray outfit with hose and nozzle or gun, and with this he will do all of his spraying. In general, satisfactory work can be done with this equipment, the important thing being for him to deal out good doses of rough justice at the right time to the pests. In many localities, however, conditions may be such that this system will not bring results. Labor may be of such a careless type that it would be inadvisable to equip the machines with guns in hot weather because of the danger in burning the foliage. In spraying for aphids in windy weather the spray-rod will allow better coverage in the higher branches, it being necessary to spray "against the wind" for this pest.

[1] Childs, L., Ore. Agr. Exp. Sta. Bull. 171. 1920.

The experienced orchardist will change the equipment to suit conditions. Depending on these conditions, there are places for the spray-rod and nozzles, for the guns, and times to use the tower.

It may be assumed that the gun is the standard nozzle which will be used through the largest range of conditions. However, only the most careful operator will spray with a gun on very hot humid days, because drenching the foliage and fruit

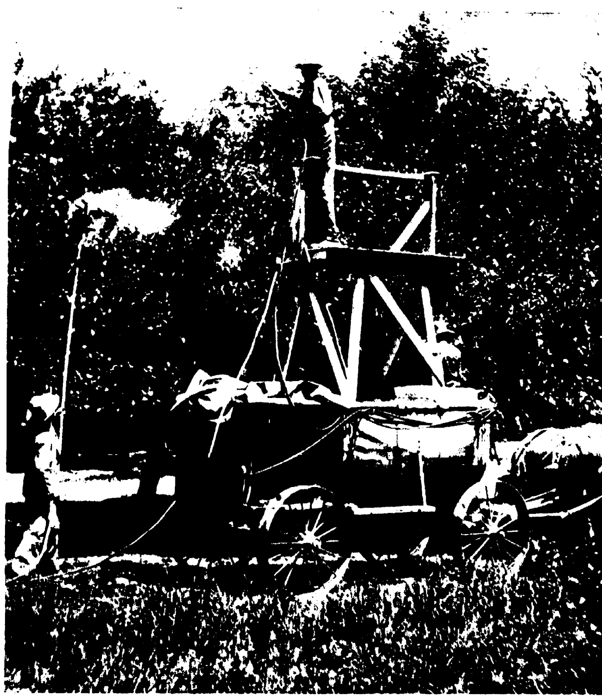


FIG. 38.—Spraying with rods, nozzles and tower.

under such conditions might cause serious burning. On such days the spray-rod and disc-nozzle is a more satisfactory implement for average help. The capacity of the outfit will frequently prohibit the use of the spray-gun. Often a spray machine will not run to full capacity and perhaps only 200 pounds pressure can be developed. In this case the careful operator will switch over to the rod and nozzles because more economical work can be done with them with lower pressures. The insect to be combated will also determine the type of equipment to be used. For example, in spraying the under side of foliage on low trees against the leaf-hopper, it is difficult to use a gun because this necessitates pushing in under the branches in order to reach the inner sections of the tree, where the drip of nicotine spray may be very distasteful to the operator, and the chances of nicotine poisoning greater, particularly in hot weather. A ten-foot rod can be inserted without much trouble and a thorough application can be made. If a sprayer cannot be made to give enough pressure to operate a gun with a breeze blowing, the substitution of a bordeaux nozzle which throws a driving spray may be satisfactory.

The nature of the materials also influences the selection of the nozzles. Wettable sulfurs tend to clog even the best types of disc-nozzle unless a very large orifice is used. The spray-gun gives the best results with wettable sulfurs and self-boiled lime-sulfurs, and there is little danger of burning with these only slightly caustic materials even on warm humid days, except possibly the "burning" due to driving the spray against the fruit and foliage with great force.

The height of the trees will determine in a measure the equipment to be used. Childs, of Oregon, has shown that after the 22-foot mark is reached, no spray-gun, even when operated most efficiently, will give satisfactory control when used from the ground. It is necessary, then, to use a tower and either another spray-gun or a rod. This again may change

the type of equipment, as only the largest sprayers will carry two guns, and it may be necessary to add a rod.

Lastly, the capabilities of the men operating the machines have a bearing on the equipment to be used. The chief cause of dissatisfaction with a spray-gun is that uninterested low-grade labor wastes material and injures foliage by careless operation. The gun is satisfactory only in the hands of an experienced careful operator, who will change the adjustment constantly as the conditions demand.

METHODS OF APPROACH TO TREE

There is considerable difference of opinion among authorities on spraying as to the proper way to cover a tree, and it is possible that no definite rule can be laid down which will meet all cases. It is generally agreed, however, that the most desirable way is to cover the entire tree at one visit. This means that the bulk of the spraying must be done from the ground.

If one lead of hose is used, spraying is done at right angles to the wind, but if two leads of hose are employed it is necessary to go with and against the wind in order that one operator will not be drenched with spray. The operator first walks under the tree and covers thoroughly the inside branches, leaves, and fruit. If extension rods are used, it can be done without getting under the tree by thrusting the rod in toward the center from various positions, and turning it about so that the angle nozzle will completely cover all sections.

Having completed the under and inner spraying, the operator walks around to the lee side of the tree and sprays back into the wind until that side is covered thoroughly, working around toward the rig with the nozzle turned as much as possible into the wind so that the lee surfaces are covered. The windward side will be covered by the drift and by a few broad sweeps on the windward side. As the operator works on around to the

lee side again the nozzle should again be slightly turned to the wind so as to coat the lee surfaces.

The tree completed, he turns the nozzle off, and moves up the row to the lee side of the next tree and repeats the operation. It is well to shut off the nozzle occasionally to observe the results of spraying, the wet surfaces being easily identified by the glossy appearance. In case the tops are not reached, it will be necessary to put a man on the tower to cover this section (Fig. 38). If the machine is of too small capacity to carry two leads of hose, it may be necessary to cover the lower branches of the tree first from the ground, and then drive over the orchard again with a man in the tower covering the tops.

Another method, which is very economical of labor and material, is to spray one side of the row at a time. This should only be used, however, when there is little or no wind. The operator first sprays the under and inner branches of the tree from a position near the trunk and then coats the side on which the sprayer is being driven, passing on immediately to the next tree where the same operation is repeated. When the end of the row is reached, the machine is driven back on the other side of the tree, the operator coating that side as he passes. If the team walks very slowly, it is frequently unnecessary to make a stop on this return trip as all of the inner branches of the tree have been covered from the other side. The advantage of this method is that the operator does not have to lug a heavy hose around, nor does he have to walk as far.

A third method which has found great favor, in at least certain sections of the country, is "spraying with the wind." By this system one side of the tree is sprayed merely by driving past the tree and waving the rod or gun around without stopping the team. Notation is made of the direction of the wind and further spraying is delayed until a wind of the opposite, or approximately opposite, direction occurs, when a similar coating is given the other side.

There are many objections to this system—so many, in fact,

that they more than counterbalance its ease and rapidity. It will not control aphis at the time of the delayed-dormant spray, because the aphis always cluster on the lee side of the buds and with a change of wind they alter their positions so as to remain on the lee side. Examination of many large blocks of trees which had been given a heavy coating of spray following this method has indicated that as far as aphis control was concerned the application had given practically no results. A large number of eggs of rosy aphis which have not yet hatched can be destroyed by spraying with the wind.

In the second place, this method is impractical in sections having continued winds from one quarter, because occasionally the prevailing wind will blow for as much as a week or ten days from one direction, and it is impossible to get the opposite sides of the trees coated before the insects or diseases which are being combated have done their damage. This is especially true of the calyx spray, the spray for curculio, which comes seven days following the calyx spray, and the first- and second-brood codlin-moth side-worm sprays, injury from which may develop with considerable rapidity and reach large proportions before a shift in the wind occurs. In one orchard of several hundred acres in New Jersey where spraying with the wind is practiced, the grower waited thirteen days for a change of wind at the time of the petal-fall spray.

Satisfactory spraying against the wind is of great value to the orchardist and is an operation requiring considerable practice. If a careful examination is made of a tree after an inexperienced or careless sprayer completes it, it can be seen that there are large dry areas in all parts. These are due largely to the wind which blew the mist away before it struck those portions. Only by shooting the material directly toward the lee sides of the leaves and twigs can one be sure of coating all surfaces. The wind blows the spray back onto the windward side, and thus an even and complete application may be given. The objection is raised that the operator gets cov-

ered with the material. In using a gun in a breeze this is frequently true. If the operator is using a spray-rod or an extension gun like the master pilot or Keith angle gun (see Fig. 22) it is possible to stand at one side of the drift. An experienced operator can usually keep well out of this drift, even with a spray-gun.

Modifications of these methods of spraying can be seen on almost every large farm. The writer has observed the use of two machines following each other closely; two men with two leads of hose on the first machine tending to the inner and the outside and lower portions of the trees, in two rows, while the second machine with a man on the tower finished them. In many warm humid sections some growers use a non-caustic fungicide, and by employing a driving spray and a nozzle with a very large orifice can so coat the inner and under portions of the branches while riding on the machine that it is unnecessary to climb under the tree to complete the job. However, a large machine is necessary to furnish enough material and pressure to accomplish this, and the machine is running at considerably below its capacity while the operator is coating the outer and upper portions of the tree with the nozzle partially closed. This point should be stressed: spraying involves a large amount of heavy physical labor, and this can be avoided only by some sacrifice of efficiency and thoroughness. If the men are trained to do the spraying correctly at the beginning of the season and are not allowed to fall into shiftless habits of spraying with the wind and riding on the tank at all times, it will be easier to keep them on the ground doing a thorough job.

METHODS OF UTILIZING EQUIPMENT AND LABOR

Efficient use of labor and equipment is essential if the grower is to cover large acreages with a reasonable number of machines and men. There are many different methods of organizing the spraying. The outstanding points in increasing spraying efficiency are the arrangement of the supply of water

and materials, the utilization of labor on machines, in mixing materials, and the reduction of loss of time in making repairs.

Arrangement of water supply

Regardless of the type of crops, the availability of water for spraying purposes is of the utmost importance. It is more important in spraying orchards than in field crops, because the latter are annuals and are usually moved from field to field in crop rotation, while orchards are sprayed in the same fields year after year. It is, therefore, economical to spend considerable money and time in developing an efficient water supply for orchard spraying. Three methods are commonly used.

The first involves the erection of a large central supply reservoir located near the center of the orchards, to which each machine returns to get a new load (Fig. 39). This has several advantages. It is possible to maintain a man whose duty it is to make up batches of materials ready to pour into the sprayer as soon as it arrives, so that a minimum of time is spent at the filling station. If a large number of machines are in use, it may pay to have a trouble man located at the central station whose duty it is to see that the machines are properly filled with oil and gas and that they are running efficiently. This trouble man is convenient to all of the orchards, so that he can make a quick trip in case any machine breaks down in the field. Another advantage of the central supply house is that it gives the spraying foreman a good check on the efficiency with which the various crews are working, and it keeps him informed of the progress of the spraying operations at all times. Finally, it is a simple and inexpensive system, involving little piping and less machinery to get out of order.

The principal disadvantage of the central supply house is that long trips are involved between it and the outlying orchards. This loss of time is balanced in a measure by the rapidity with which filling is accomplished and the greater efficiency through having the machines looked over by the

trouble man between trips. For the most distant orchards, *supply wagons may be sent out which reload the sprayers in the field and eliminate the long pull to the central supply house.* Another modification of this system which serves to eliminate waste of time is the operation of a relay of machines, so that only one man, the driver, is forced to make these trips. Another disadvantage is that in case there is a serious accident to the

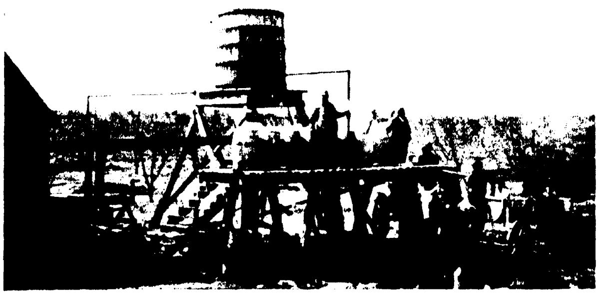


FIG. 39.—Well arranged filling station. Self-boiled lime-sulfur or dry-mix sulfur-lime is prepared on the platform and dumped into the spray-tanks as they drive up below.

water supply or some other important cog in the system at the central point, it may throw out the whole spraying force until repairs are effected.

Where several sprayers load at the central spray shed, it will be well to have sufficient filling platforms there so that there will be no delays. It is not an uncommon sight in large orchards to see two, and even three or four sprayers standing in line, waiting to be filled from one water pipe.

The second method of arranging the water and material supply is the maintenance of a number of small filling stations scattered at convenient points throughout the orchards. These operate like small central filling stations, except that they are

visited by only one or two sprayers. In this way, all long hauls may be eliminated, but the men are forced to make up their own batches of material and the engines and pumps do not receive the supervision that they do at large central supply houses. In case of breakdowns there is always a wait until the mechanic is located. One great advantage in the small unit system is that an accident to any one of these small supply houses does not tie up the spraying operations, as the sprayers thus affected can haul from the nearest supply house which is in working order.

The third method of organizing the spraying is a central pumping plant and direct piping of the orchard. This method is discussed in detail in Chapter VIII. This system is analogous to the first system discussed here, except that the spraying operations are not scattered about the orchard to as great a degree and are more easily supervised.

Regardless of the method of organizing the spraying, a large water reservoir (Figs. 40, 41) is a good investment. It should hold enough water to run the sprayers for several days, lest an accident prevent securing additional water for a short time. A concrete reservoir or a small lake, natural or artificial, is one of the best sources. Wood-stave tanks are efficient and durable, but are scarcely large enough for a central reservoir if a large area is to be sprayed. For storing water when only two or three sprayers are being operated, a tank holding from 5,000 to 10,000 gallons is sufficient, as this if full will run two sprayers for two or three days. Steel tanks are expensive to buy and install but are durable. A wood-stave or concrete tank can frequently be set up by the crew on the place. The reservoir should be erected so that a gravity flow of water can be used to fill the spray-tanks.

Supply of materials

A sufficient stock of necessary materials should be laid in long before the spraying season opens. A rough estimate of the

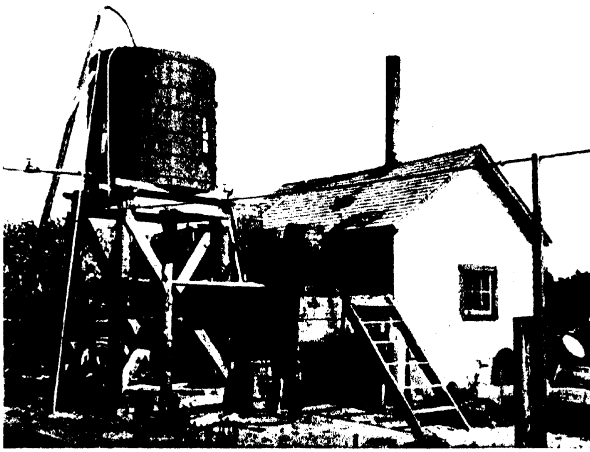


FIG. 40.—A good water supply and filling station, but inconvenient platform arrangement.

FIG. 41.—Engine and pump at reservoir; central supply house in orchard above.

total supply needed can be arrived at, and this should be ordered early, both to avoid danger of transportation delays and to take advantage of lower prices which usually prevail on spray materials during the late fall and early winter.

Materials should be arranged conveniently in the supply house and separated by unmistakable divisions, so that even the most unintelligent laborer cannot confuse them. The writer knows of one case in the season of 1923 when a grower with 4,500 trees used hydrated lime for arsenate of lead in all of his early spraying, due to a mistake in identifying the packages. Containers with unmistakable colors such as red for lead arsenate, yellow for sulfur, white for lime, are advisable. The storage rooms for materials should be at the filling station so that no time will be lost in mixing up batches. Accurate scales and a plentiful supply of containers with which to measure out liquid materials should be available. Extra buckets, strainers, paddles, and scales should always be on hand, as these supplies wear out rapidly and must be replaced frequently.

No matter whether a grower has five acres or five hundred, if he has a spray machine he should have a supply of parts on hand so that his operators will not be held up in the midst of his busiest season by slight breakdowns. The completeness of the stock will depend somewhat on the distance to the nearest supply house or repair shop, the size of stocks held there, and the speed with which these supplies are usually sent. Some of the manufacturers of spray machinery have built up a reputation for quick attention to letters or telegrams asking for parts. Other manufacturers are notably negligent in dispatching repair parts required. There are a few single fittings which should be on hand for every machine, and as rapidly as they are used they should be replaced, because there is no forecasting the vagaries of a sprayer, and occasionally a part which would normally do for several months will give out after only a few days' use. These supplies should be kept in a

convenient dry place, and metals should be coated with grease to keep them from corroding. A cabinet in the spray shed is an excellent place for small supplies. A grower operating five or more machines should have a well-equipped machine room with ample tools.

Parts Needed in Well-Equipped Supply Room

For Grower Operating over 10 Sprayers

For Grower Operating 5 to 10 Sprayers

For Grower Operating 1 to 5 Sprayers

Article	*Quantity per 1 machine*
Pump packing	1 box
Plunger cups	2 sets
Valve seats	1 set
Valve balls	1 set
Pistons	1 or 2
Connecting rods	1 or 2
Gaskets	3 sets
Nozzle discs	3 per gun
Leather hose washers	2 dozen
Suction hose strainer	1
Spray-hose	50 feet
Spark-plugs	2
Valve springs	1 each
Cylinder-head gaskets	2

	Quantity per 5 machines
Piston rings	3 sets
Engine pistons	2
Engine connecting rods	2
Cylinder head	1
Drive: chain, gears, or yokes	2
Agitator paddles	3
Suction hoses	2
Tank	1
Pump drive shaft	1
Agitator drive: chain or gear	2

	Quantity per 10 machines
Complete extra sprayer	1
Complete extra engine	1
Complete extra pump	1

The manning of the spraying outfit depends on several factors such as the size and capacity of the outfit, the method

to be adopted of covering the trees, and the accessories. For the single-cylinder duplex and very light triplex outfits, on which only one lead of hose can be used, it is obvious that only two men are required, one to drive and the other to distribute the spray. On an outfit with a capacity of twelve to fifteen gallons a minute, where two leads of hose can be used, the most economical way to utilize labor is to have three men—a driver and two sprayers—operating either on one row if the trees are large, or each taking a separate row if the trees are small. In case of large trees, one man should be in the tower while the other should spray from the ground. These men can alternate jobs between tanks of material. On the machines of largest capacity, which will carry three leads of hose, two rows should be sprayed at one time, two men on the ground each taking a row, and one man on the tower covering the tops of the trees, as each stop is made. The latter method is perhaps the most efficient for growers who have large acreages and who have difficulty in getting over the area, but it requires machines of large capacity, 3- to 4-cylinder pumps and 6- to 15-horsepower engines, preferably.

Another method, economical of labor, combines some of the ideas of the stationary spray system with the portable method. A spray outfit with a large tank, preferably 300 to 500 gallons, is equipped with two leads of hose, each from 100 to 125 feet long. This outfit, manned by two men, is driven down between the third and fourth rows of trees, stopping between the second and third trees in the row. The tractor engine is stopped and the driver handles one of the spray-guns. Six trees in each of the two rows behind the machine are sprayed, and the hoses are dragged into the two rows ahead of the machine, where three trees on each side of the sprayer, in each of these two rows are sprayed. The first man to finish his rows starts the tractor and moves the outfit forward four rows, and the same procedure is repeated. Thus twenty-four trees are sprayed at each stop. A minimum of labor

is used, and the tractor operated a minimum amount of time.

The field of the hand-sprayer and tank-sprayer is very limited, and little can be said on the utilization of man power in operating these. The pump can be operated with one man at the handle, although it will be impossible for him to work up more than 100 to 125 pounds pressure or supply more than one lead of hose with an extension rod and single disc-nozzle. These small pumps are most efficient when mounted on skids and they can be thrown into any sort of a farm wagon. They should only be used when there are a small number of trees to be sprayed for which investment in a larger outfit would be uneconomical.

Keeping the sprayer running

In these days of high pressure spraying, especially when the machines are called on for fairly continuous service in many orchards or gardens, it is indeed an art to keep the sprayer running efficiently. These machines are somewhat temperamental, and considerable patience is often required in tuning them up. The grower who hunts trouble in a systematic way will usually get best results. After a person has become thoroughly familiar with an outfit he learns to look for certain things which most commonly cause difficulty. The following outline will give hints as to possible causes of engine and pump troubles.

Guide for locating engine troubles

I. Failure to start.
   1. Lack of fuel—examine gasoline tank; test gas line to see that supply reaches carburetor; prime carburetor.
   2. Mal-adjustment of carburetor—open needle-valve control to a little past point indicated in direction book as best for steady running. When engine is warm it may be turned back.
   3. Water in gas—drain carburetor.

4. Lack of spark—be sure switch is on; if battery system is used turn engine over to "dead center" to establish contact. Vibrator should buzz. If no buzz results, examine all connections lest one be loose or broken; examine wiring chart to see that wiring is properly connected. Examine spark-plug; clean it if dirty, setting points apart the width of a thin dime. If connections are tight, turn vibrator-spring adjustment back and forth one or two turns to try to make it buzz. If no buzz is forthcoming or buzz is intermittent and weak and batteries are old, test them with ammeter. Replace all testing less than 10 amperes with new ones, which should test from 16 to 20 amperes. Test points on vibrator to see if they are pitted and burned. If so, file until smooth and reset, adjusting it so that the loudest possible buzz ensues. Remove spark plug, but leave wire attached. Hold plug against metal part of engine with vibrator buzzing and look into plug. If spark is jumping across down inside the plug, it is defective and should be replaced with fresh one. If still no spark is forthcoming, it may be that coil in coil box is burned out or short-circuited; if so, replace with new one. Examine switch to see that oil or water has not collected on it. Blow water off of switch, spark-plug, and wires, as water slopping out of engine frequently short-circuits the ignition. If buzz is obtained when engine is on "dead center" and spark-plug fires correctly and regularly as engine passes "dead-center" mark, yet engine will not start, look elsewhere for trouble.

   If magneto ignition is used, remove spark-plug and with wire attached allow it to rest against metal on motor. Set impulse lever at starting position and turn engine over slowly. When "dead center" is reached, if spark does not jump the plug points, try new spark-plug. If no spark ensues hunt trouble in magneto, following magneto guide-book.
5. Flooded engine—perhaps engine has become flooded with gasoline from protracted cranking. Shut off gasoline of needle-valve on carburetor, and holding intake valve open crank for a minute; or remove

spark-plug and touch a light into cylinder, keeping hand out of way. When done replace plug, open needle-valve, turn on switch, and crank.

6. Engine flooded with oil—if oil has been allowed to run freely into cylinder head, turn off oil, clean spark-plug, and allow engine to run until white smoke ceases to come from exhaust. Turn on and adjust flow of oil to amount indicated in guide-book (usually 4 or 5 drops a minute).
7. Engine cold—engines frequently are hard to start on very cold mornings. Fill water-jacket with hot water, prime engine by pouring thimbleful of gasoline in spark-plug hole. Hold hand over air port in carburetor until firing starts.

II. Failure to run properly.

1. Black smoke exhausted from muffler—this indicates too rich a mixture; close needle-valve on carburetor until black smoke ceases and engine runs properly.
2. White smoke exhausted from muffler—this indicates too much oil; shut off oil flow from oil-cup until smoking ceases; turn on again and adjust flow so that no smoke is exhausted.
3. Engine boiling—fill water-jacket; see that oil supply is sufficient; adjust needle-valve on carburetor to remedy too lean or too rich mixture, clean off carbon deposits, if any, in the engine. If the engine still heats it is a sign it is too small for work demanded of it.
4. Lack of power—poor carburetor adjustment; too much oil; engine running too hot; carbon deposits in engine.
5. Lack of compression—if engine turns over easily by hand it may be due to pitted and worn valve seats or worn piston-rings. A good mechanic should grind valves and if necessary replace piston-rings.
6. Misfiring or intermittent explosions—caused by water in gasoline; drain the carburetor and gas tank and refill with pure gasoline. Caused more commonly by short-circuit in ignition: use tests for loose or broken connections; water or oil on switch, spark-

plug, or wires; defective spark-plug; dirty spark-plug; weak spark; mal-adjustment of vibrator spring; defective coil; pitted or burned vibrator points; and dirty timer.

7. Backfiring—spark too early, retard control lever; short-circuit on primary wire, wires to wrong points; carbon in engine.

Guide for locating pump troubles

I. Failure to develop pressure.

1. Pump and valves dry and need priming—only occurs on suction feed pump; pour water down suction hose and turn engine over a few times.
2. Clogged feed pipes—examine end of suction hose and open up valve under gravity feed pipe and clean out.
3. Sticking valves—occasionally valves stick when sprayer has been standing for long period; examine intake valves first, then others in turn.
4. Air leak in feed line— tighten all connections. This is a common trouble and frequently difficult to locate.

II. Failure to maintain pressure.

1. Clogged valves, also spoken of as stuck valves—due to sediment or obstruction catching under the valve and holding it open. Frequently can be located by opening the guns into the tank and then synchronizing the pump stroke with the falling of the pressure indicator. Whichever piston stroke the pressure drops on will usually be the one for which the valves are stuck. Clean valves and allow material to flood through them before replacing balls so as to be sure all sediment is removed.
2. Clogged pressure regulator valve—sediment sometimes collects under the stem or ball operating the by-pass valve on the pressure regulator, holding it open all the time. Clean it out.
3. Leaky pistons—usually indicated by loss of spray material around the pistons. Tighten packing nut until leak stops; worn-out packing, replace with fresh packing; worn-out plunger cups on ends of pistons, replace with new; worn plungers, replace if tightening

the packing nut or replacement of packing does not permanently stop leaking.

4. Air-pocket under valves—open guns wide until spitting of air from nozzle indicates its removal; close guns and wait for pressure to rise.
5. Worn or leaky valves—this is the most common cause of failure to hold pressure. Valve seats should have sharp edges so that balls fit snugly. If worn to more than 1/16 inch in width replace or regrind the seat.
6. Worn balls—occasionally gritty materials like wettable sulfurs will wear the valve balls away until they are not round. This is especially true in the pressure regulators. Replace worn balls.
7. Clogged line—rarely one of the passages through the pump becomes clogged, requiring a careful examination and thorough cleaning with a heavy wire.
8. Sticking of pressure regulator—sometimes the packing around the stem operating the pressure regulator becomes dry and stem sticks. Remove packing nut and fill with grease or replace packing.
9. Mal-adjustment of pressure regulator—this usually comes properly adjusted, and merely needs to have the tension on the spring screwed up. However, occasionally the adjustment of the stem is faulty. Follow guide-book carefully in adjusting this stem.
10. Failure to pump air into air-chamber before allowing spray to flow to pumps. Close valve leading from tank to pumps. Allow all pressure to escape. Start pumps, and run until 25 to 50 pounds of pressure are registered by indicator. Then open valve allowing the liquid to run down from tank to pumps.
11. Overloading spray-pump by use of too many leads of hose or too big discs. (See Chapter VII about capacities of sprayers.)
12. Running pump below speed—check up on strokes a minute of pump, compare with catalog or instruction book, and adjust motor speed accordingly.

Under any circumstances the methodical checking up on trouble is to be recommended over the strong-arm method.

Many a man with a monkey-wrench has done more harm than good to a machine.

It should be kept in mind also that many spray machinery troubles are preventable by reasonable care. Pumps and hose should be washed out after each day's spraying. Engines which continuously run hot should be drained and refilled each time the sprayer is loaded. Attention to oiling markedly extends the life of a spray machine.

At the end of the season's spraying operations, the engine and pump should be drained of water, the hoses removed, and kerosene or old lubricating oil run through the pump and allowed to stand in it over winter. The sprayer will then be in good running condition when the season opens the next spring.

CHAPTER X

DUSTS AND DUSTING

DUSTING has certain advantages over spraying. They are as follows:

1. Less time is required for application of dusts than for sprays. With a large modern outfit 25 to 35 acres of mature apple orchard can be dusted in a nine- or ten-hour day, while 40 acres of peaches and 20 to 30 acres of vegetables can be dusted in the same length of time. When applications must go on at certain definite periods this time-saving is an important factor, as the modern sprayers with high pressures and large capacities can rarely cover more than 6 or 7 acres of mature apple orchard, 8 of peaches, or 8 to 10 of vegetables in one day. It is entirely possible that the advantage gained by getting the protective coating on at more nearly the right time will offset some of the disadvantage in the possible lower effectiveness of the powdered material.

2. Less labor is required for dusting. Labor and time are closely allied topics, but when there is an actual shortage of man-power, labor becomes a more important item. Especially in those agricultural areas bordering on the industrial districts has the shortage of labor been felt most keenly, and this has interested many growers in dust applications.

3. No water supply is essential and the time hauling water from the pumping plant is saved. Materials for a half day's dusting can be carried on the machine or left in convenient places in the orchard. This is especially important in isolated orchards, or where water is not easily available.

4. Less motive power is required. The use of dusters neces-

sitates less implements for a given acreage, thus freeing horse or tractor labor for other work.

5. A duster, costing $425 at this writing, will cover 75 acres of mature apple orchard, requiring an investment of less than $6 an acre. A sprayer costing $600 will cover 30 acres, requiring an investment of $20 an acre.

6. Sulfur-arsenical dust applications are less caustic than liquid concentrated lime-sulfur-arsenical sprays and cause less burning. There is frequently better finish to the fruit on dusted blocks, especially in sections in which burning has resulted from the use of concentrated lime-sulfur sprays now commonly applied.

7. Dusting materials and machinery are light compared to spraying equipment, and can readily be drawn through the orchard when the heavier sprayers would bog down. A duster of the maximum capacity now on the market, with a hopper full of dust (100 pounds) weighs less than a large empty spray machine.

8. Dusting may be done when the trees are damp with dew, or shortly after showers, while spraying must wait until the trees are practically dry. Thus advantage often can be taken of lulls between storms when spraying would be impractical.

9. The hand-duster may be used in a limited way with less trouble and inconvenience to the backyard gardener than a hand-sprayer, and good results may be secured with it.

Some of the disadvantages of dusting, as compared to spraying, are:

1. The materials for dusting are more expensive than for spraying. This difference is usually more than can be made up by that in labor cost.

2. Nicotine applications, so essential to the control of aphis, cannot be applied as efficiently to fruit-trees by the dusting machine as by a sprayer. However, nicotine-dust applications are generally more effective than liquid-nicotine applications on vegetable crops.

3. Dormant dusts are not as efficient as dormant sprays.

4. A spray machine is needed for the dormant spray; and on a small farm it may be used for all spraying instead of tying up money in extra equipment for dusting.

5. The control of some diseases and insects by dust has not been as fully worked out as for spraying methods.

On no topic has there been more general disagreement among the growers and investigators than on the question of dusting vs. spraying for the control of pests affecting principally the apple. There is fairly general agreement that dust is as effective as spray when used in the normal growing season for controlling the insects and diseases affecting the peach. Most investigators agree also that nicotine dust is valuable for the control of aphis on truck crops. The authorities are generally of the opinion that for such crops as the potato, where copper and copper-arsenicals must be used, the dust applications are not as effective as the copper arsenical sprays unless the new colloidal copper dusts prove satisfactory. While the accord is not unanimous, it is fairly generally recognized that pests affecting the apple, with the exception of scab and aphis, can be controlled by dust materials. The chief bone of contention is the control of apple-scab.

In New York, where Reddick, Whetzel, Glasgow, Hesler, and others have led in investigating the dusting problem, it was first definitely established that sulfur dusts would control apple-scab. Sanders, of Nova Scotia; Dutton, of Michigan; Johnston, Fromme, Ralston, and Eheart, of Virginia; Fagan and Thurston, of Pennsylvania; Krout, Doran, and Osmun in Massachusetts; Freeman, of Minnesota, and others have reported experiments substantiating the New York results. On the other hand, Cullinin and Baker, of Indiana; Blair of Nova Scotia; Britton, Zappe, and Stoddard, in Connecticut; Martin and Farley of New Jersey, and others have not been as successful in the scab control with dust as with spray.

From the fruit-grower's viewpoint. many factors must be

taken into consideration. In running experiments, both the spray and the dust are applied at as nearly the right moment as possible. The scientists agree that for the control of scab the timeliness of the application is of paramount importance. In actual farm practice it will often be impossible to apply the liquid spray at exactly the right time, due to the magnitude of the task. Some of the trees will be sprayed earlier and some later than the optimum time. In dusting, the orchard can be covered more nearly at the optimum time. Thus, under farm conditions, the comparison might be more favorable to dust than it is under experimental conditions.

Split applications of dust—*i.e.*, dividing the full amount required for the tree into two equal parts, applying one part from one side at the optimum time and the other part from the opposite side five to seven days later,—were not generally used in experiments. While the system involves more time, it is said to give better control.

Dusted fruit generally has higher finish and color than sprayed fruit in sections where lime-sulfur or bordeaux mixture burns. The higher market value due to color and finish may more than offset the penalty imposed for slight differences in scab infection between sprayed and dusted fruit, if such differences are found.

In seasons when bad weather prevails, it may be possible to get dusting done when spraying would be impossible. In sections where labor is limited and high priced, making it impossible to man a large enough number of sprayers properly to cover the orchards, the use of dust may make it possible to protect the orchard.

Summing up the dust vs. spray question regarding the control of apple-scab, it can be said safely that:

1. Ample experimental evidence shows that in some places dust has been equal to spray in years of bad scab infection and on varieties susceptible to scab.

2. Many large orchards are being successfully dusted at

the present time, and fruit of as good or better quality is grown with dust as had previously been produced with spray.

3. Where labor difficulties make it impossible properly to spray an orchard, a thorough dusting is to be recommended over an inefficient job of spraying.

4. Inasmuch as scale and aphis are still controlled more efficiently with liquid applications than with dust, it is essential that orchardists should own one or more good sprayers. These should be used for the dormant spray, and for as much of the pre-pink and pink-bud sprays as possible, these latter sprays being the ones particularly important in controlling scab.

5. All orchardists who are relying on liquid spraying may well own modern dusting equipment to be used when spraying is impossible, or to supplement the sprayers when the spraying applications are running behind. It is good insurance.

6. Growers now relying on liquid sprays are to be cautioned against making a change from spraying to dusting without first trying out dusting in a small way, or at least becoming thoroughly familiar with the practice in their own sections. Evidence is still too conflicting on the question to warrant empirical recommendations for the use of dust alone.

Liquid sulfur, copper, arsenical and nicotine sprays are still the standard materials to be relied on in controlling or preventing attacks of orchard and garden pests. Dusting shows great promise, and has outstanding advantages which make the perfection of dusting practices something to hope for and to seek diligently. There seems to be little doubt that dusting materials and methods will be markedly improved in the near future, and with this improvement will come a wider general use of the dry materials and a certain reduction in liquid sprays. The day for unequivocal recommendations of dusting is not yet at hand, but indications are that it will soon dawn. Until then the orchardist and gardener must consider the liquid sprays the standard materials.

DUSTING MATERIALS

Sulfur and dehydrated copper sulfate are the two principal fungicidal materials now used in dusting. Sulfur has been employed more generally and with greater satisfaction than copper. For tree-fruits in the United States, sulfur is used practically altogether. In some of the cooler latitudes, particularly in Nova Scotia, copper dusts have gained considerable foothold. Both lead arsenate and calcium arsenate are largely utilized as stomach poisons, and nicotine dust as a contact insecticide.

Sulfur dust

An extremely finely divided sulfur running at least 98 per cent pure is desirable for dusting purposes. The importance of fineness cannot be overemphasized. The particles should be small enough to pass a 300-mesh sieve (90,000 opening to a square inch). H. C. Young has shown that colloidal sulfur, being impalpably fine, has better fungicidal properties than any other known forms. He says danger from burning foliage is reduced by reducing the fineness of the particles of dust. All of the early investigations with dusts were done with coarse material, and it was doubtless due in a large measure to this factor that so little success attended those efforts. When finely divided dusts were adopted, giving a thin film of dust on the leaf more nearly approximating the film left by the application of concentrated lime-sulfur, better results were at once secured. Adhesiveness is increased with fineness. Most of the manufacturers of dusting sulfurs will furnish dusts 80 to 95 per cent of which is guaranteed to pass through a 300-mesh sieve. Manufacturers have on the market dusts coated with stickers, which increase their effectiveness considerably. These are more expensive.

Sulfur when applied alone rarely causes burning. It can be combined safely with lead arsenate, calcium arsenate, and hydrated lime. Sometimes nicotine sulfate in a lime carrier is

combined with it. This lowers the fungicidal value of the dust, however, because it is necessary to use such a considerable amount of nicotine carrier, which is non-fungicidal.

Pure sulfur dust, or proper combinations of sulfur, lead arsenate and lime, are used for apples, peaches, pears, and cherries for the control of the common insects and diseases during the growing season. Soda-sulfur dust is employed in a limited way as a dormant dust. The effectiveness of this material against heavy infestations of scale is problematical.

Copper dusts

Copper-sulfate dusts are made by driving off the water of crystallization from copper sulfate, and grinding the remaining material so that it will pass through a 300-mesh sieve. This material was first used by G. E. Sanders, of the Canada Experimental Farms, Kentville, Nova Scotia, where it gave considerable promise and was widely adopted as a fungicide for apples. However, when used on fruits further south it caused severe burning of both fruit and foliage, and has been largely discarded for this purpose.

Potato and vegetable-growers have found it of some value as a substitute for bordeaux mixture and it is used to a small extent for this purpose. As with sulfur dusts for the control of scab, the investigators disagree widely on the practicability of using the present copper-lime dusts as a substitute for bordeaux mixture. The consensus of opinion seems to be that it is unsatisfactory for controlling late blight on potatoes, but that it can be utilized with considerable success on such crops as tomatoes, cucumbers, melons, and other vegetables. The use of this material will doubtless increase with further development and improvements of the materials.

Copper-sulfate dust must be mixed with quantities of lime. When this mixture comes into contact with moisture on the leaf, a combination resembling bordeaux results. The usual formulæ call for 15 to 20 per cent copper-sulfate dust, 60 to

65 per cent hydrated lime, and 15 to 20 per cent lead arsenate or calcium arsenate.

Copper-carbonate dust, made by driving the water of crystallization from copper carbonate and finely grinding the compound, is used to a considerable extent for the treatment of seed oats and wheat for smut. Copper sulfate is said to repress root growth and also to reduce the stand, while formaldehyde represses plumule development. Copper-carbonate dust used at the rate of two ounces to a bushel completely controls smut without affecting germination and growth.

Lead-arsenate dust

Lead arsenates are applied with hydrated lime or sulfur dust as a carrier. Finely divided lead-arsenate dust, which will pass through a 300-mesh sieve, is desirable. Most commercial brands are guaranteed to be from 80 to 95 per cent, 300-mesh size or smaller. Inasmuch as lead arsenate is such a concentrated poison, only from 5 to 15 per cent is used in a mixture, 85 to 95 per cent of the bulk being taken up by the sulfur or the hydrated-lime filler. Occasionally where such insects as leaf-roller or canker-worms are present, a stronger dust is used, sometimes running as high as 50 per cent lead arsenate.

When tender foliage, such as that of the peach, nectarine, or Japanese plum, is to be dusted with lead arsenate, some lime should always be included in the formula. The amount of lime will vary somewhat with the climate. In hot humid sections such as New Jersey or Delaware, 5 per cent lead arsenate is used with 20 per cent hydrated lime and 75 per cent sulfur. In cooler latitudes or higher altitudes, where temperature and humidity are not so great, a mixture containing 10 per cent lead arsenate, 10 per cent hydrated lime, and 80 per cent sulfur may be employed with safety on such tender fruits.

Lead arsenate, mixed with a diluent, is used on all of the

fruit crops, and can be applied to vegetables and cotton, but calcium arsenate is frequently substituted on these latter crops. It can be combined with sulfur, copper sulfate, lime, and occasionally with nicotine mixtures.

Calcium-arsenate dust

Calcium-arsenate dust, ground finely enough to pass through a 300-mesh sieve, is a valuable stomach poison for controlling cotton boll-weevil, potato-bugs, and other chewing insects attacking vegetables. It can be combined safely with lime, sulfur, and copper-sulfate dusts, but equal quantities of lime must accompany its use with sulfur and copper compounds for safety. It is not recommended as an arsenical poison for fruit-trees.

FIG. 42.—Dusting peas with nicotine dust and hand-duster in southern California.

Nicotine dust (Fig. 42)

This dust, one of the last to be developed, has become perhaps the most popular of all forms, especially because of its effectiveness in controlling aphis on vegetable crops. Ground tobacco dust has been unsatisfactory because of the wide variation in nicotine content secured from different tobaccos, and because of the slow evolution of nicotine from these

materials after application. D. E. Haley, of the Pennsylvania State College, has recently developed some strains of *Nicotiana rustica* which yield a very high percentage of nicotine. This tobacco is ground and used as a dust. Several hundred acres are being grown in Pennsylvania for this purpose.

The first nicotine dust was made and used by the California Walnut Growers Association at Santa Barbara, as a contact insecticide for walnut aphis. R. E. Smith, of the California Agricultural Experiment Station, undertook the development of it, and since then it has received wide attention in all parts of the United States. The usual method of manufacture has been the impregnation of a carrier, such as lime, with a definite amount of nicotine sulfate. Variations in carrier and in forms of nicotine have occurred since.

Two forms of nicotine are used in the manufacture of nicotine dust—the 40 per cent nicotine sulfate, and the so-called 95 per cent free nicotine. Headlee and Rudolfs, of the New Jersey Agricultural Experiment Station, and Thatcher and Streeter, of the New York (Geneva) Agricultural Experiment Station, report that the nature of the mineral carrier has an important effect on nicotine volatilization and consequent efficiency of the dust. They state that there are three types of carriers used in the commercial manufacture of nicotine dust: (1) absorbent or colloidal materials such as Kaolin, talc, and Kieselguhr, which tend to prevent that volatilization of nicotine; (2) crystalline powders, such as gypsum, sulfur, and slate dust, which are inert and have no effect on volatility, but simply present large surfaces for evaporation; and (3) common hydrates and carbonates, such as carbonate of lime and hydrated lime, which are active in that they change the nicotine sulfate into a more volatile form. The change produced by active carriers (group 3) is dependent on a small amount of water in the mixture, such as is supplied in commercial solutions of nicotine sulfate. Too much water slows up volatilization by dissolving the alkaloid and interfering with the dust properties of the mixture.

There is also a difference in the quantity of nicotine delivered by the various carriers.

There is a tendency among the manufacturers toward the use of the solutions containing the higher percentages of nicotine, although some still claim that nicotine sulfate containing 40 per cent nicotine is just as satisfactory. The free nicotine solution is more expensive and the dusts made with it consequently cost more. The superiority of the dusts from free nicotine is due to the greater and faster evolution of nicotine gas in a given period of time.

Headlee and Rudolfs of New Jersey [1] recommend the use of a dolomite, or magnesium limestone, as a carrier for free nicotine in the dusting of ground crops. It is cheap, effective, available, adheres well, and does not burn the plants. However, dolomite has a high specific gravity and this great weight makes it an unsatisfactory dust for trees unless lightened with some other material. Therefore, they recommend 75 per cent hydrated lime with 25 per cent dolomite as a good carrier for nicotine sulfate for the dusting of orchard crops, and the dolomite should be ground to a fineness that would allow it to pass through a 300-mesh sieve.

Nicotine dusts can be bought ready mixed, packed in tight containers. These should be kept closed and as full as practicable, because the mixture loses strength rapidly when exposed to the air. As stated above, the carrier and the use for which the mixture is to be put should be determined by the crops to be dusted. This will also determine the strength. In general, aphis on ground crops can be killed with lower concentrations of dust than aphis on tree crops. Strengths of 1½ to 3 per cent are required on ground crops, when a hover or curtain is used on the duster to hold the dust around the plants (Figs. 43-45). For the same insects on the same crops, it will require from 2 to 4 per cent nicotine dusts if the curtains are not used, due to the diffusion of the gas before it has a toxic effect on the insects. For aphis on tree-fruits nothing less

[1] Headlee, T. J., and Rudolfs, W., N. J. Agr. Exp. Sta. Bull. 400. 1924.

than 3 per cent will kill, due to the fact that the free air movement through the tree does not allow the aphis to get a great enough concentration of the gas for it to be toxic. For apple red-bug weaker concentrations can be employed, 1½ per cent being sufficient to give control of this insect under favorable dusting conditions.

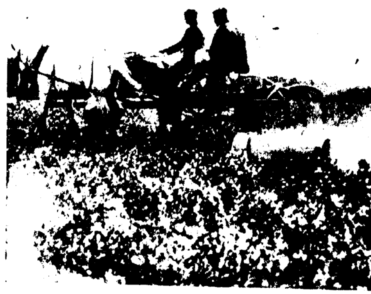


FIG. 43.—Side view of metal trailer for use on vegetable row crops.

The strength of nicotine in a solution is expressed in two ways: (1) by the actual percentage of total nicotine in the mixture; and (2) by the percentage of 40 per cent nicotine sulfate in the mixture. Growers are cautioned to note carefully which measure is used when strengths of various nicotine dusts are recommended or discussed. A 2 per cent nicotine dust contains two and one-half times as much of the actual killing ingredient, nicotine, as a 2 per cent nicotine-sulfate dust. In this manual the strength of nicotine dusts is expressed in terms of actual


FIG. 44.—End view of trailer.

total nicotine in the mixture. The difference between the two is as follows:

Percentage Expressed in Quantity of Nicotine-Sulfate Solution (Containing 40% Nicotine) in Dust		*Percentage Expressed in Quantity of Pure Nicotine in Dust*
2	equals	0.8
4	equals	1.6
5	equals	2.0
6	equals	2.4
8	equals	3.2
10	equals	4.0

Nicotine dusts may be mixed at home with considerable success. R. E. Smith, of the California Agricultural Experiment Station, designed a self-mixing attachment for a standard

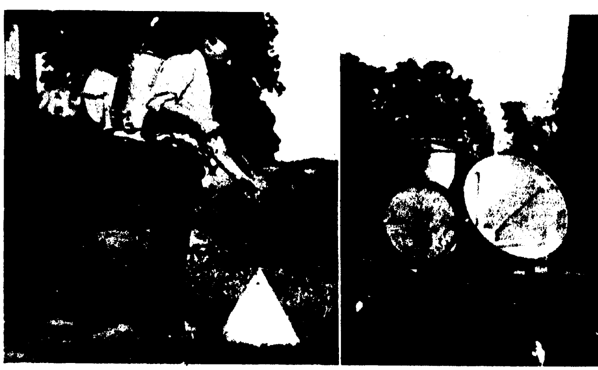


FIG. 45.—Desirable type of hood for hand-duster. The dust is ejected through fan-shaped tips at the base of the hood. These tips direct the dust up under the plant.

dusting machine when he was working with walnut aphis. This idea was incorporated into the models of prominent dust machines and is giving excellent results. Samples of the mix-

tures taken from different parts of the hopper after self-mixing show surprisingly uniform strengths. The advantages of home mixing are as follows: (1) the dust is cheaper, being limited practically to the cost of raw products alone; (2) there is no loss of nicotine from storage; (3) any desired strength can be made as needed; and (4) it is hot from the mixing process and therefore somewhat more active. However, where the home mixing has to be left to untrained help the danger of using wrong dosages with consequent lack of control of insects is, perhaps, too great to be risked, and for these growers, and for any grower using only limited amounts of dust, the ready-mixed dusts are strongly recommended.

Inasmuch as the use of nicotine dusts is dependent on the ability of the gardener to procure readily a fresh supply of material, and because thus far there is not a very widespread distribution of nicotine dusts in rural communities, it may frequently be necessary for the grower to make his own. Nicotine sulfate containing 40 per cent nicotine and high grade hydrated lime (the finishing lime used by plasterers is satisfactory) are essential. Where magnesium limestone is available it may be used in place of the calcium lime for vegetable dusts.

The following formulæ are indicative of the proportions in which nicotine dusts may be prepared. Other mixtures may easily be calculated and made. Sulfur may be used in place of part of the lime if desired.

FORMULA No. 1

3 per cent nicotine dust, equivalent to 7½ per cent nicotine sulfate dust.

Materials	*For 10 lbs.*	*For 100 lbs.*
Hydrated lime	9¼ lbs.	92½ lbs.
40% Nicotine sulfate	12 oz.	7½ lbs.

FORMULA No. 2

2 per cent nicotine dust, equivalent to a 5 per cent nicotine sulfate dust.

Materials	*For 10 lbs.*	*For 100 lbs.*
Hydrated lime	9½ lbs.	95 lbs.
40% Nicotine sulfate	8 oz.	5 lbs.

White[1] suggests that the materials be sifted and the required amount of nicotine sulfate added slowly, and mixed thoroughly by stirring. For small quantities of material the final mixing may be given by sifting once or twice through an old flour sifter. For larger quantities, a larger sifter or sieve is necessary. White designed a box (Fig. 46) with a detached cover, in which a sieve is placed, and a floor-brush attached to a handle may be used to brush the dust through the sieve into the hopper below. A slot in the side allows the handle to protrude so that the cover may be kept on the box during the screening. Two or three siftings are desirable. The screen should be made of brass, and contain twenty meshes to the inch.

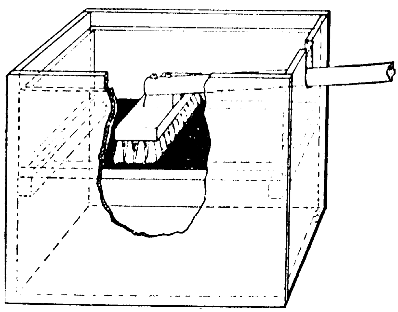


Fig. 46.—Box sifter for preparation of nicotine dust.

Another convenient method of mixing is to place the hydrated lime and nicotine sulfate in a rotary churn, with some smooth stones of the size of eggs. Turning the churn for five minutes will thoroughly mix the dust. A satisfactory rotary churn may be made from a small keg, with iron pipes for axle and handle.

Special equipment must be provided for the dusting of ground crops with nicotine dusts. Booms are used to direct the dust into each row. To hold nicotine dusts as long as possible about the plants, and to prevent the wind from inter-

[1] W. H. White, Nicotine Dusts for Control of Striped Cucumber Beetle, U. S. Dept. Agr. Circ. 224. 1922.

fering with this kind of dusting, various arrangements have been worked out. The most common one is a long canvas trailer or drag which is attached behind the duster, under which the discharge pipes vent their dust. The length of this canvas varies from 10 to 40 feet, being limited by the difficulties involved in turning at the ends of the rows and the possibility of injuring the plants. The weight of the canvas

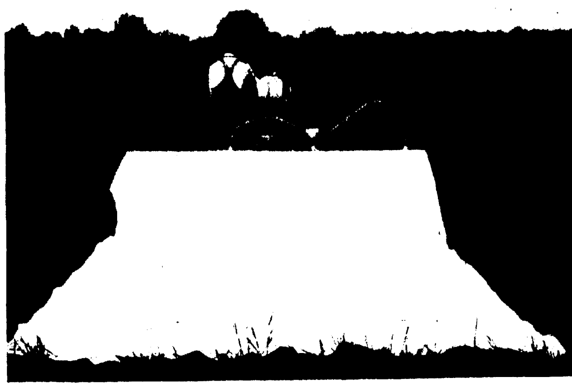


Fig. 47.—Vegetable crop duster, with canvas trailer.

is an advantage up to a certain point in that it knocks off many aphis, and these are rendered more susceptible to the dust by their activity. Another weighted canvas must be hung in front of the discharge pipes to keep the material from blowing out in front. Metal trough-like attachments are also used, which fit down over the row and into which the dust is discharged. These are particularly useful when there is sufficient wind blowing to make the use of the canvas impractical. (See Fig. 43.)

The time of application of nicotine dusts differs materially

from usual dusting practice. The dusts derived from free nicotine solutions are most efficient when the temperature is high and humidity low, while those from nicotine-sulfate solutions are most efficient when both temperature and humidity are high. Wind tends to lessen the effectiveness of dust, blowing the gases which are evolved away from the insect before they have had deadly effect.

Nicotine dusts can be mixed safely with other insecticidal and fungicidal dusts without impairing their volatility, except those which contain anhydrous copper sulfate. This material takes up the moisture that is necessary to change nicotine into more volatile forms. If moisture is added to replace that lost to the copper sulfate, the mixture cakes and loses its dust properties.

ORCHARD AND GARDEN PRACTICE

Time of application

The time to apply all dust materials, except nicotine dusts, is usually in the early morning or late evening when the air is calm. At that time the atmosphere is heavy and quiet, less dust is required to cover the trees, and the dust cloud hangs about the tree like a pall. This is a very important factor in obtaining control of insects and diseases. There is more moisture on the surfaces of the leaves during these hours, causing the material to adhere better. This is especially necessary when copper-lime dust is used. Sulfur dusts stick in a fairly satisfactory manner even when the foliage is entirely dry. One should avoid dusting in strong breezes. Many growers equip the dusting machine with lights run from the magneto or from a storage battery and do much of their dusting at night. This not only enables them to take advantage of calm atmosphere, but even allows for two shifts of men, one in the daytime and the other at night. When dusting European grapes for mildew, applications should not be made when the temperature falls below 70° F.

Nicotine dusts, on the other hand, must be applied when the temperature is high. This is usually at midday. Only still days should be chosen for this work. The longer the dust cloud hangs about the insect, the greater will be the kill. If constant winds prevail at midday, it will be better to apply nicotine dusts in the slightly cooler still hours of the day rather than in hot windy hours, because the wind movement in blowing the nicotine fumes away from the insects will more than offset any advantage gained from the heat. It must be recognized that nicotine dusts are not very effective when the temperature gets below 70° F., and higher temperatures are desirable.

When fungus control is desired dusting before rain-storms is the ideal practice. The weather reports should be scanned for predictions of an approaching storm and an application made before it strikes. This is possible in small orchards and in areas where rains during the spring seasons are not abundant. The theory of dusting before rains rests on the fact that fungous diseases are preventable but not curable, and spores of many of these diseases, such as apple-scab and bitter-rot, are discharged in great quantities during protracted rains and are blown about the orchard. If they light on sulfur-covered surfaces no damage will result, but if the leaves and fruit are not protected infection will occur. Portions of orchards not dusted before rain-storms should be covered immediately after. It is true that much of the dust will be washed off by very heavy rain-storms, but enough will remain to give protection for some time. From the standpoint of disease control, without rain there will be no infection and therefore it is more essential to have the protective coating on the foliage and fruit before and during the rain rather than after it.

Organization of work

Organizing the work is an important step. The proper materials should be selected, and supplies sufficient for a half

day or the entire day should be placed on the machine or left in convenient places after the orchard is reached. Distributing the sacks of dust at the ends of rows is a convenient method because the least time is then lost in refilling the hopper. The amount of material to a tree to be applied should be decided and the feed control lever set as near that adjustment as possible, to be corrected when a row has been treated, or when the first hopperfull of dust has been applied, by which time the actual rate of application can be calculated. If small trees requiring less than one pound to a tree are to be treated, the fastest walking team should be used, while if large trees requiring one to two pounds a tree are dusted a slower team is best (Fig. 48), the slowest team being used on trees requiring over two pounds to a tree. It should never be necessary to stop the team.

Covering the tree is an art which is developed with a little experience. When small trees having considerable space between them are being dusted the material is "puffed" on them; *i.e.*, the feed lever is opened as the discharge pipe passes the tree, the tree enveloped in the cloud of dust, and the dust flow shut off again. Sufficient movement of the discharge pipe should accompany the puff to cover the tips of the tree. It is only necessary to dust from one side.

When large trees are dusted, it is necessary to apply the material from both sides. This can be done by driving up one side and down the other. If much drift of wind prevails it may be necessary to wait until the drift is in the opposite direction. This has developed the so-called "split application" which has proved so successful in dusting apple orchards. The trees are dusted on one side at the optimum time, using half the total amount of dust required fully to cover the tree. Five to seven days later the other side of the tree is covered, using the remainder of the material. An evener coating is thus maintained on the surfaces of the fruit and foliage, and in those sections of the country where from five to seven summer sprays

are required it means that a dust application must be made to one side or the other about once a week. Splitting the application is not recommended when applying nicotine or dormant dusts.

The discharge pipe should be moved in such a way as to distribute the material evenly over the whole surface of the

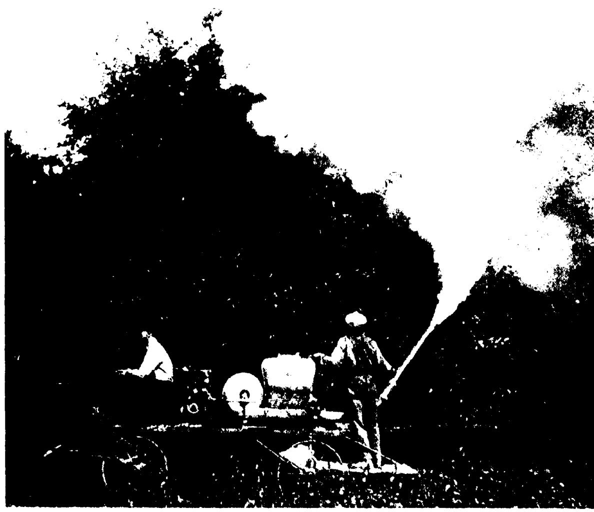


Fig. 48.—A slow-walking team is necessary when trees are tall and dense.

tree. A sweeping up-and-down movement is best, with a broad stroke across the top of the tree and, as the machine draws away from the tree, another stroke behind, covering the tips of the lower branches thoroughly. A little experience will enable a careful operator to get maximum coverage with a small

amount of material. In dusting very high trees it is occasionally desirable to have an extension on the discharge pipe. Greater altitude can be attained by a quick upward flirt of the pipe at the top of each stroke.

The flow of dust is regulated by moving the feed control lever to the desired point. Notches or other fastening devices hold it from slipping. Attention should be given to the amount of dust applied each time the hopper is emptied to see that the proper number of trees is covered with a given amount of material.

The amount of material to apply will differ with the size of the tree. The following table made by the Niagara Sprayer Company gives suggested amounts for trees of different ages. These figures refer to trees of average size for their ages and are indicative rather than exact. They should be varied according to necessity in orchards where peculiarities in growth have made them above or below the ordinary.

Quantity of Dust to Use at Each Application [1]

Crop	Amount to a Tree				
	1 to 5 Yrs.	5 to 10 Yrs.	10 to 15 Yrs.	15 to 20 Yrs.	Above 20 Yrs.
Apples	1/8 lb.	1/4 to 1/2 lbs.	1 lb.	1 1/2 to 2 lbs.	2 to 3 lbs
Cherries	1/8 "	1/4 "	1/2 to 3/4 "	1 "	1 to 1 1/2 "
Oranges and grapefruits	1/8 "	1/4 "	3/4 "	1 "	1 to 1 1/2 "
Peaches	1/8 to 1/4 "	1/4 to 1/2 "	1/2 "	1/2 "	1/2 "
Pears	1/8 "	1/4 to 1/2 "	1/2 to 3/4 "	1 "	1 "
Pecans	1/8 to 1/4 "	3/4 "	1 to 1 1/2 "	2 to 2 1/2 "	3 to 5 "
Plums and prunes	1/8 "	1/4 "	1/2 to 3/4 "	1 "	1 "
Quinces	1/8 "	1/4 "	3/8 to 1/2 "	1/2 "	1/2 "

Vegetable dusting practice

Vegetable dusting schedules are available from many different state experiment stations. Aphids are widely prevalent on vegetable crops. The time of application depends on the appearance of the insect. Dusting at the beginning of the outbreaks of aphis is far more satisfactory than after they have

[1] Niagara Sprayer Co. Bull. 245. 1924.

become established, both because there are fewer aphis to be controlled and because they have not yet done their damage or become curled up in the leaves.

The time to dust vegetables depends on the materials used. When sulfur or copper-lime dust is to be applied, the damp still parts of the day are best. Both adhere best to damp

FIG. 49.—Crop duster in operation. Note that the nozzles direct the dust in from each side of each row.

leaves. If copper-lime dust is applied when the plants are dry, the proper reactions between the copper and lime in the dust will not take place. When nicotine dusts are used they should be put on in the heat of the day, preferably when the air is calm.

In dusting tomatoes, potatoes, eggplants, and similar crops with a fungicidal or arsenical dust, the nozzles should be turned slightly downward (Fig. 49), and set fairly close together for young plants. As the vines increase in size, the nozzles are spread out and the dust flow directed straight out.

In dusting with nicotine dust for aphis, the dust current should be directed upward on to the under sides of the leaves, or so that the leaves will be blown over, exposing the aphis on the under surfaces.

In dusting cucumbers and melons (Fig. 50) the vines must be dragged into the row by the cultivator so that the team and wheels of the duster will not injure them. In combating

FIG. 50.—Dusting cantaloupes with power-duster on sled.

aphis the nozzles are arranged so that they are almost parallel to the ground, shooting only slightly downward. This will blow the leaves back, exposing the aphis on the under sides to the dust. In dusting for blight, anthracnose, downy-mildew, and other fungous diseases, the nozzles are turned to shoot downward upon the vines.

In dusting strawberries for weevil, the nozzles should be aimed straight down upon the rows and placed close to the tops of the plants.

In dusting grapes the nozzles should be pointed directly

toward the vines, except when combating leaf-hopper, when the nozzles should be set in a low position, pointing upward so as to strike the under sides of the leaves. One nozzle should be aimed at each wire of the trellis. Two rows should be dusted at one time.

The quantity of dust necessary for different vegetable crops is as follows:

QUANTITY OF DUST FOR EACH APPLICATION [1]

Crop	Amount to the Acre	Crop	Amount to the Acre
Asparagus	9 to 12 lbs.	Potatoes—Continued	12 lbs. at first application when plant is 6 inches high.
Beans	20 to 30 lbs.		18 lbs. at second application.
Bush-fruits	25 to 30 lbs.		25 lbs. at third application.
Cabbage, cauliflower, and kale	20 to 35 lbs.		30 lbs. at fourth application.
Celery	30 to 40 lbs.		35 lbs. at fifth application.
Cucumbers, melons, and squash	6 to 8 lbs. D-11 Dust for beetles 15 to 30 lbs. of copper dust		Need 35 to 40 lbs. on full-grown vines.
Grapes	25 lbs. For leaf-hopper use 35 lbs. D-11	Spinach	20 to 30 lbs.
Onions	25 to 30 lbs.	Strawberries	35 to 45 lbs.
Peas	30 to 40 lbs.	Tobacco	1 lb. a square rod in seed-bed. 10 to 20 lbs. in field.
Potatoes	Average 20 to 25 lbs. per each application throughout entire season	Tomato	15 to 30 lbs.

Dusting practice with hand equipment (Fig. 51)

The dust treatment of fruits and vegetables with hand equipment is more difficult but often quite as successful as the treatment with power equipment. The simplest hand-duster is a grain sack which is jarred or shaken above the plant to be treated. However, this will not control aphis, which are on the under sides of the leaves. For these some form of blower must be used. Three types are on the market. The simplest is the dust-gun, or plunger type. The second has a bellows which puffs the material, while the third has a fan which produces a sustained flow of air. The first two are best for individual plants, while the latter has the advantage of a con-

[1] Niagara Sprayer Co. Bull. 245. 1921.

stant discharge for row crops. The nozzle of each type of duster must be adapted to the needs of the work. A fan-shaped nozzle can be used to spread the dust out when treating the tops of plants for fungous troubles, while a nozzle with an upturned outlet so that the under sides of the leaves may be hit is necessary for the treatment of aphis.

The acreages which can be covered with hand outfits will vary with the crop. In combating onion thrips, 2½ to 3 acres

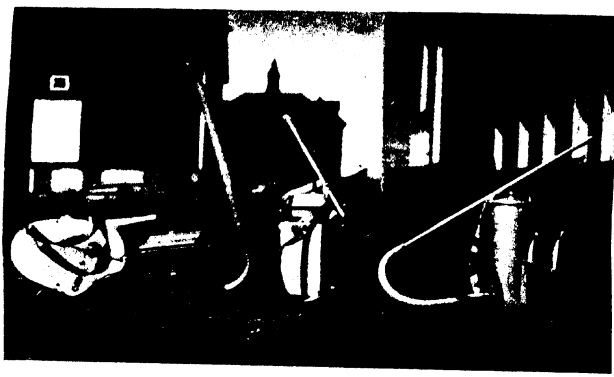


FIG. 51.—Some types of hand-dusters. From left to right: Springfield, Niagara, Vermorel, Walnut Nicoduster, American Beauty. The first two are fan or blower dusters.

a day may be covered, using dust at the rate of 30 to 50 pounds an acre. Cucumbers can be dusted at the rate of almost 1,000 hills an hour, while full-grown melon vines can be covered at the rate of 2 acres a day.

Higher concentrations of nicotine are generally required when hand-dusters are used to combat aphis, except when the outfit is equipped with a hover to hold the dust in contact with the insect for a moment. As high as a 4 per cent nicotine dust may be required to kill the cucumber-beetle

if no hover is used, but 2 per cent nicotine dust will be sufficient where a curtain or hover holds in the dust.

Hand-dusters of all three types can be used on bush-fruits, grapes, and small trees, but the gardener who wishes a hand-duster for fruit-trees should have a fan type, as a sustained flow is more desirable (Fig. 52). With a hand outfit it is relatively easy and practical to dust a few low peach, plum, quince, or sour-cherry trees. Large apple trees are more difficult. The lower branches can be covered from the ground, but the upper reaches can only be treated by using a ladder or climbing the tree. The air must be very still. Gardeners have covered a dozen or more very large trees in this way, getting entirely satisfactory control of insects and diseases. The ladder should reach to the top of the tree on the windward side, pro-

FIG. 52.—Using a hand-duster in a small orchard.

viding there is a slight drift to the air and ample dust is used completely to envelope the tree. If the air is absolutely still, the ladder can be placed up through the center of the tree, or the tree can be climbed and the dust aimed out over the branches from a position near the topmost branches.

Present tendencies in dusting

Developments in manufacture of dust materials and machinery, and improvements in methods of application will be watched with interest by grower and scientist alike during the next few years. In no other phase of pest control is there as much possibility of revolutionary changes. Investigators and commercial agents are bending much effort toward establishing this practice on a firmer basis.

The tendency is toward the use of more finely divided materials and more powerful machinery. Within the two years of 1926 and 1927 the standard of fineness was raised from 200-mesh to 300-mesh, while dusts are on the market today in which there is, in addition to the 300-mesh particles, a large percentage of colloidal material of impalpable fineness. Large fans, driven by more powerful engines, are being used on dusters, one company using a 14-horsepower engine to drive a proportionately large blower in 1927. This is about double the capacity of other machines then in use. Increasing power and capacity give the operator more control over the elements, it being difficult to dust even in only light breezes with machinery heretofore built.

The aeroplane, used experimentally for several years past, has been adopted widely for dusting cotton in the South. The next few years may see its use extended to orchards in intensively developed fruit districts.

CHAPTER XI

FUMIGATION

CERTAIN substances give off fumes which are toxic to undesirable organisms. These materials are called fumigants, and the operation fumigation. Many pests which resist control by spraying are easily subdued by this means. It is particularly valuable as a method of controlling pests in greenhouses, warehouses, and dwellings where spraying is not practicable, and for

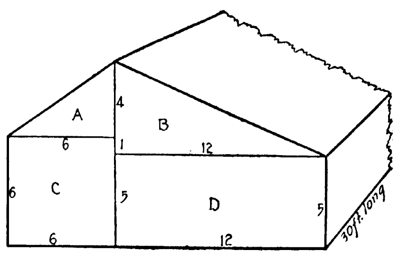


FIG. 53.—Diagram for determining the cubic contents of a house.

combating scale on citrus trees. Chemicals used commonly as fumigants are hydrocyanic-acid gas, carbon disulfid, paradichlorobenzene, sulfur, and nicotine.

The first step in fumigation is the calculation of the size of the room to be treated. For rectangular spaces this can be obtained easily by multiplying together the length, breadth and height. For greenhouses the area of one end is calculated and this figure multiplied by the length of the house. The end of a three-quarter span house is divided as illustrated in Fig. 53, and the area of each part ascertained, the sum of these parts

being multiplied by the length of the house. Exact calculations are essential.

The end should be plotted into right triangles and rectangles, and the area of each obtained, and added to get the total area—*i.e.:*

The area of triangle a is	½ (4 x 6)	= 12	sq. feet.
The area of triangle b is	½ (5 x 12)	= 30	sq. feet.
The area of rectangle c is	6 x 6	= 36	sq. feet.
The area of rectangle d is	5 x 12	= 60	sq. feet.
	(added)	138	sq. feet.
Length of house	(multiplied)	× 30	feet.
		4140	cu. feet = total capacity.

The second step is the determination of the dosage necessary to kill the pest. In greenhouses this will be affected by the plants to be treated. The resistance of plants to fumes varies greatly. Ferns will stand only ¼ ounce of hydrocyanic-acid gas to each 1,000 cubic feet of air space, while on chrysanthemums 1 ounce may be used. Violet foliage is particularly sensitive to tobacco fumes and is never fumigated with this material. Sensitive plants requiring low concentrations must be given correspondingly longer exposures to kill the pests. Tightness of construction must be considered also—an air-tight space requiring much less fumigant than one in which there are cracks.

The third step is to calk crevices and openings, arranging for the opening of windows and ventilators from the outside after fumigation is completed. All moist or absorbent foods should be removed, and any furniture or equipment which will be acted on by the fumes should be taken out. Hydrocyanic-acid gas, for example, will injure nickel and brass fittings.

FUMIGATION WITH HYDROCYANIC-ACID GAS

This material is the most deadly and effective fumigant in common usage, but due to the danger incident to its use it

should be handled only by expert operators. It is not particularly combustible, so the danger from fire, as with carbon disulfid, is largely eliminated. Liquid hydrocyanic acid, calcium cyanid and sodium cyanid are employed for this purpose.

Calcium cyanid

This new source of hydrocyanic-acid gas is rapidly superseding liquid hydrocyanic acid and sodium or potassium cyanid, because of the extreme ease of use. It is becoming well known by the name "cyanogas." The outstanding advantages of the material are that it is very easy to handle, doing away with the clumsy pots and sloppy corrosive acid, and substitutes in their place a clean simple material which evolves gas through reaction with the moisture in the air. Also, with other forms of hydrocyanic gas the maximum concentration of gas was reached within a few minutes after the generators were charged, while with calcium cyanid in granular form the gas is given off over an extended period of time, kills being effected as well by long exposure to low concentrations of the gas as by shorter high concentrations.

Calcium cyanid is available on the market in three forms, the dust, the flakes and the coarse granules. The coarser the particles the longer the evolution of gas and consequent lower concentrations for a given amount of material. When high concentrations, quickly available, are desired, the dust form is used, as in fumigating for certain insects on resistant foliage. When slower evolution of gas is desirable, as in fumigating the soil for wireworms, the coarser forms are better.

Among the important uses already found for calcium cyanid are greenhouse fumigation, citrus fumigation, rodent control, dusting for pear psylla and aphids on horticultural crops, soil fumigation for wireworms, grubs, chinch-bugs, while the Kansas Agricultural Experiment Station has found it promising as a fumigant for dwellings.

Burrowing rodents, such as ground-hogs, woodchucks and

squirrels may be controlled with calcium cyanid by placing from 1½ to 2 ounces of the flakes in each burrow. The flakes and granules have been found much better adapted to rodent eradication than the calcium cyanid dust. The material is placed as far down the runway as possible, and the burrow is not closed, thus effecting a considerable saving in time over the method of eradication with carbon bisulfid and other materials. The material is more effective when the ground is moist.

For greenhouse fumigation calcium cyanid has largely replaced sodium cyanid. It is merely sprinkled on damp floors in the evening, and the house is closed tightly. The gas has been dissipated by morning. From ¼ to ⅓ ounce to every 1,000 cubic feet is used to kill white-fly, thrips, aphis, and green-fly. Fumigation for an hour with as strong a concentration of gas as the plant will stand has been found to kill more insects and to leave the plants in better condition than longer exposures to weaker gases, but because of the convenience and less danger to the plants many growers still fumigate all night, using very low concentrations.

All fumigation should be done at night when the temperature has dropped below 75° F., but while it is still above 55° F., according to Weigel and Sasscer [1] of the United States Bureau of Entomology, and it should not be done when the wind is high or on hot humid nights, and never in the daytime. The exposure should not exceed an hour, after which the house should be opened for ten to thirty minutes at least, depending on the weather. Before fumigating, any broken glasses should be replaced and the house made as nearly air-tight as possible. The ventilators should be adjusted so that they can be opened from the outside. This can usually be done with ropes attached to the levers operating the ventilators. In case a person is

[1] Weigel, C. A., and Sasscer, E. R., U. S. Dept. Agr. Farmers' Bull. 1362. 1923.

Fig. 54.—Scattering calcium cyanid in greenhouse.

made ill by the gas, he should be kept moving and forced to inhale ammonia fumes. A bottle of ammonia should be kept handy. Plants should not be watered just prior to fumigation with hydrocyanic-acid gas, but the morning previously. Fumigation may be done either with calcium cyanid or with 98 to 99 per cent pure sodium cyanid. If sodium cyanid is used the crocks containing the materials should be as evenly distributed as possible.

Weigel[1] gives the following directions for applying calcium cyanid in greenhouse fumigation:

"After determining how much calcium cyanid is necessary, weigh out the required quantity and place it in a wide-mouthed bottle or other container. Then scatter it evenly on the surface of the center walk or path (Fig. 54), beginning at the far end, and, walking backward, working toward the door. A convenient container for scattering calcium cyanid may be made from a baking powder can by puncturing holes in the cover from the inside, using a 10 penny nail. A wide mouthed glass jar with a perforated metal top can be used instead, and the glass jar enables the operator to watch the rate of distribution. Do not place the cyanid in the can or jar until ready to fumigate. Because calcium cyanid gives off gas when exposed to the air, the container in which it is stored should be kept tightly closed, and the quantity set apart for a given fumigation should be kept in a stoppered bottle or other secure container until about to be used. When spreading the material, be careful that none of it comes in contact with the plants. For larger greenhouses divide the material equally and scatter on two or more walks, depending on the width of the house. In such cases it is safer for one not to fumigate alone, but to have an operator for each path in which the calcium cyanid is to be applied.

"Calcium cyanid must not be placed in piles, as is customary in fumigation with nicotine or tobacco, because the atmospheric moisture could not readily reach the inner portion of the pile, and probably not all the gas would be given off. Moreover, the gas evolved would not be evenly diffused throughout the greenhouse."

[1] Weigel, C. A., U. S. Dept. Agr. Circ. 380. 1926.

Sodium cyanid

The mixture of sodium cyanid, sulfuric acid and water in proper proportions gives off hydrocyanic-acid gas. The following proportions are advised [1] for use in warehouses or closed buildings:

Sodium cyanid (98-99% pure)....	1 lb. (avoir.)
Sulfuric acid	1½ pts.
Water	3 pts.

This quantity will be sufficient for a warehouse room containing 1,000 cubic feet. For greenhouses, however, the dosage should never be more than ½ ounce to 1,000 cubic feet; and if roses, snapdragons, ferns, geraniums, or other tender plants are grown, not over ¼ ounce to 1,000 cubic feet should be used, or the plants will be injured.

The sodium cyanid also comes in ounce molds specially prepared for fumigating, and this is the form most generally used in greenhouses. One ounce will be sufficient for 4,000 cubic feet if the greenhouse is tight. If construction is loose the quantity must be doubled. In fumigating warehouses or dwellings 1 ounce will only fumigate 100 cubic feet, providing construction is tight; if construction is not tight the charge must be doubled. The formula for the small quantity is as follows:

Sodium cyanid (98-99% pure).....	1 oz. avoir.
Sulfuric acid	1½ oz. fluid
Water	1 oz. fluid

As most storehouses will contain several thousand cubic feet, the most convenient way to fumigate is to use crockery jars of about 4-gallon capacity. These will hold 3-pound charges of cyanid—enough for 3,000 to 4,000 cubic feet each. The jars should be set on old carpeting or newspapers to avoid damage in case any of the acid splatters out. The procedure is as follows:

1. Calculate capacity of room and secure sufficient generating crocks.

[1] Howard, L. O., and Popenoe, C. H., U. S. Dept. Agr. Farmers' Bull. 699. 1916.

2. Remove all moist or absorbent foods and nickel or brass furniture. Remove carpets and rugs from spots where generators are to stand. Fill generators outside, putting water in first, then adding acid slowly to prevent boiling and splattering.

3. Carry generators into rooms and place them on papers or sacks, to prevent damage in case the material splatters.

4. Break up the cyanid outside into egg sizes and put proper amount for each generator into thin paper sacks, placing proper sack at the side of each generator.

5. Start at top of building, gently dropping each bag of cyanid into its generator, and quickly leave the room, passing to each successive floor until the basement is reached, leaving the building by a basement door.

6. Lock the building and place signs on doors, calling attention to the presence of dangerous fumes within. Leave it closed at least six, or better twenty-four hours.

7. Open windows from outside and wait for at least an hour before entering. If odor of cyanid, like peach kernels, still lingers, wait until it has disappeared.

8. Empty remains in generators in a safe place—such as down a sewer trap—and wash crocks thoroughly before using for domestic purposes.

A single apartment cannot be fumigated very well without having the entire building vacated. If the house construction is loose, there is danger to persons in contiguous houses. Cyanid may be handled with bare hands unless there are open sores on the hands, but it is well to wear gloves when breaking up lumps. After charging a generator by the method described above, it will be at least fifteen seconds before gas is given off and several more seconds before the gas is concentrated enough to be injurious, so there is ample time to leave a room.

Caution is again advised in handling these materials. Hydrocyanic-acid gas is one of the most deadly poisons known. A small particle of sodium cyanid eaten will cause quick death. However, if precautions are taken, warehouses, bins, buildings,

and storages may be fumigated without the danger of fire which exists when carbon disulfid is used. Some of these precautions are as follows:

1. Don't handle it unless you are perfectly familiar with every step. Let an expert do it where practicable.
2. Don't taste or smell it, or handle it with bare hands containing open sores.
3. Don't fumigate parts of buildings without vacating the whole structure.
4. Don't fumigate a loosely constructed house with contiguous houses occupied, or where higher buildings adjoin, without taking proper precautions, such as having these buildings vacated.
5. Don't reënter fumigated buildings without allowing at least an hour of ventilation or until all "peach-kernel" odor is gone.
6. Don't be careless. Hydrocyanic-acid gas is deadly.

The fumigation of citrus trees with this material is discussed in detail on pages 375 to 386.

Nicotine

Tobacco fumes are used for fumigating conservatories and greenhouses to control aphis, thrips, and white-flies where the use of hydrocyanic-acid gas is inconvenient. The nicotine is vaporized by heating the liquid nicotine by painting steam-pipes with the concentrated solution, heating it in pans, or else by burning nicotine papers, these being specially prepared for greenhouse fumigation by impregnating them with free nicotine solution. The directions for dosages are given on the container and should be followed closely. Tobacco papers should smoulder rather than burn, as flames burn up the nicotine gas and lessen the effect of the fumes. The papers should be distributed through the house so as to secure an even diffusion of the gas. According to McDaniel,[1] moisture adds to the effectiveness of the fumes, and still wet nights are best for nicotine fumigation. Inasmuch as the house has to be closed

[1] McDaniel, E. I., Mich. Agr. Exp. Sta. Special Bull. 134. 1924.

for a long period in order to have the nicotine take effect, nighttime is usually more convenient. Nicotine papers should be purchased fresh as needed, as they deteriorate rapidly on standing. While nicotine papers are more reliable than tobacco dust or waste, the latter is cheaper and is still widely burned.

Delicate flower petals are easily injured by tobacco fumes; therefore, blossoms should be cut before fumigation. Violet foliage is particularly sensitive to injury by tobacco, and houses containing these plants should never be fumigated with nicotine.

Sulfur

Sulfur is used both as an insecticide and a fungicide. Its principal value is as a fumigant for mildew, for which it is made into a paste form with water and painted on the pipes while heat is on. The coating is renewed as soon as the previous application has disappeared. The sulfur fumes, slight though they may be, doubtless help to keep other fungous troubles in check.

Sulfur when used at high concentrations is a most powerful disinfectant. When houses are cleaned out, they are shut tightly, and ⅓-pound to each 1,000 cubic feet of greenhouse is burned in wide deep metal pans. Usually a fire is kindled with wood or chips, and the sulfur is poured on after the blaze is started. The pans should be distributed evenly through the house. After twelve or more hours the house may be opened and aired. Sulfur fumigation of this kind should never be attempted when any plants are in the house.

Paradichlorobenzene (P.D.B., crystal-gas, paracide)

This material, in appearance much like epsom salts, is used for fumigation of clothes closets, to kill moths, and as a general repellent for insects. It is scattered in closets as moth-balls are used. Some persons find the fumes disagreeable.

The use of paradichlorobenzene in combating the root-borers on peaches is discussed in detail on page 306.

CHAPTER XII

SOIL STERILIZATION

Treatment of the soil to destroy injurious fungus, insect, and bacterial pests is one of the practices which has become as essential in the routine of some kinds of agriculture as plowing or cultivating. The trucker who works a soil area intensively cannot very well avoid introducing many more pests than the farmer or orchardist who is handling broad field crops. The inconvenience of long crop-rotation schedules, especially when they involve leaving out some of the gardener's most profitable crops, the lack of sufficient land on the average truck farm to permit any idle areas, and the high land values prevailing in intensive gardening sections, make it essential that such farmers fight the soil pests by direct means. Obviously the greenhouse man has no alternative. Soil sterilization or fumigation is an effective solution of the problem.

These practices not alone concern the farmer. The city dweller with his lawn is just as much concerned if he lives in a district infested by such injurious insects as the Japanese beetle, or the chinch-bug. The apartment-house dweller feels the pinch of an insect attack when he sees the golf greens and fairways at his country club dotted with dead patches of turf.

Soil sterilization must be conducted most thoroughly if good results are to be expected. Many growers sterilize their soils in greenhouses or plant-beds and then use infected tools for working the soil, or they track infected soil in from the outside on dirty shoes. Such practices are analogous to a surgeon who would exercise greatest care in preparation of a patient for an

operation, only to use dirty ungloved hands and unsterilized instruments operating. When soils are treated, the benches, walks, tools, containers, and everything coming into contact with the treated soil should also be fumigated.

Sterilization affects the seed-bed in two important ways. It suppresses practically all of the injurious insects and diseases and kills weed seeds (Fig. 55). It may have certain harmful effects through the removal of beneficial soil organisms, par-

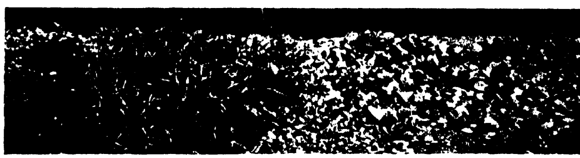


FIG. 55.—A tobacco seed-bed, showing a partition between the steamed and unsteamed portions. Both sections were sown at the same time with similar seed but the weeds in the unsteamed sections (left) practically killed the tobacco seedlings. No weeds grew on the steamed part.

ticularly those which work on decaying organic matter and these must be introduced again. Occasionally the physical condition of the soil is impaired, especially by steam and hot water sterilization.

STEAM STERILIZATION

Live steam is an efficient sterilizing agent when introduced into the soil. The most widely employed method of effecting this is by the "inverted pan." Other ways are by using covered steam-pipes, drain-tile, and the steam-rake.

A steam-boiler is an essential in steam sterilization. The greenhouse operator can use his boiler equipment in the head house, providing such equipment will maintain sufficient pressures. Most heating plants only have a capacity of 15 or 20 pounds, and while this is enough to do the work it takes two or three times as long as by the high-pressure method,

and the cost of keeping up steam for sterilization in low-pressure boilers is much greater than with a high-pressure outfit. A portable boiler of about 20 horsepower or larger capacity is the most convenient source of steam, as this will develop pressures better for soil sterilization. Boilers that will develop from 75 to 125 pounds pressure are best adapted to the work.

Seed may be sown safely twelve hours after steaming the beds. Usually growth will be retarded in treated beds so that the plants may fall behind those in untreated beds for as much as ten days or two weeks. However, their recovery is rapid, and they soon forge ahead of plants in untreated beds, and are usually ready for transplanting several days ahead of their unsterilized competitors.

More frequent irrigation is required in steamed beds, because of the rapidity with which the surface seems to dry out and crumble.

Inverted pan method (Fig. 56)

This is the most common method of steam sterilization in soils in which it is not convenient to lay permanent sterilization pipes. The outfit is highly portable and very effective. The method consists of inverting a large rectangular metal pan over the soil and introducing steam into it.

Beinhart[1] gives the following list of equipment for use with the steam-pan method:

"A portable boiler of 20 horsepower or larger capacity.

"Heavy ¾-inch steam hose, 25 feet.

"Iron ¾-inch pipe sufficient in length to carry the steam from the boiler to all parts of the beds.

"Heavy canvas or burlap, 216 square feet.

"A steaming pan to cover an area of about 72 square feet.

"Attachments for the steaming pan, consisting of four ring

[1] Beinhart, E. G., U. S. Dept. Agr. Farmers' Bull. 996. 1918.

bolts 6 inches long, with 3-inch rings; four bars or ax handles; felt packing 2 inches wide, sufficient in length to extend around the pan; the same length of 4-inch hoop iron or of 2-inch angle iron; one ¾-inch nipple 6 or 7 inches long, threaded on both ends; two ¾-inch leather gaskets; two ¾-inch nuts or threaded washers."

When seed-beds are to be steamed, the pan can be made on such dimensions as will just fit the beds. A pan larger than 60 or 80 square feet is cumbersome to handle and requires a larger boiler.

Sterilizing pans made of galvanized iron have been extensively employed, but as wooden pans are cheaper and are easily made at home, wood is the material now coming into general use. The wooden pan further possesses the distinct advantage of reducing the loss of heat by radiation. The pan is simply a shallow box, 4 inches being the preferred depth Fig. 57). If it is deeper, much of the desired effect is lost through the more rapid cooling of the steam in the larger space exposed above the soil.

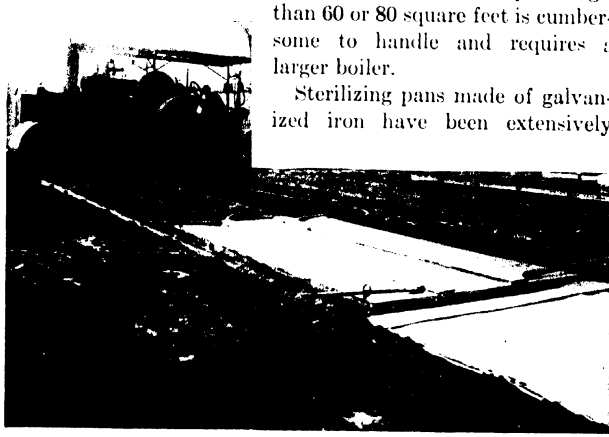


FIG. 56.—Steam sterilization of seed-beds, using the inverted pan method. A small steam boiler is just as satisfactory as the large engine.

The soil is spaded up, to permit of quick penetration by the steam. Frozen or wet soils do not sterilize efficiently. The pan is placed in position on the bed and attached to the boiler by the steam-hose. Steam at 75 to 100 pounds pressure is turned into it for half an hour to an hour and a half. One test is to bury a potato under the pan, and heat until the tuber is cooked through. After sufficient exposure the pan is moved forward, allowing a few inches of overlap. A two-

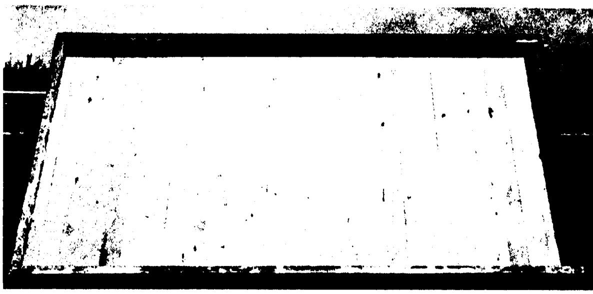


FIG. 57.—Face view of steam-pan. Note the metal flange around the pan to insure a tight seal when the pan is inverted over the seed-bed.

wheel rack, on an axle a few inches wider than the pan, can be designed for lifting and moving it, thus cutting down labor costs.

When this method is employed in a large way, two pans are operated, so that one can be moved while the other is in use. Also with this system the used pan can remain on the soil for fifteen or twenty minutes after the steam is turned off, which conserves the heat. Greater penetration, with less live steam can be secured if such a system is followed. The pans are neither so hot nor so disagreeable to handle if allowed to stand in this way. A little experience will enable the operator to secure maximum results with the available equipment.

The steam-pipe system

This is a popular method, particularly in greenhouses. Three-inch galvanized pipe, made of light material like rain-spouting can be used. Holes 1/4 inch in diameter are punched at 6-inch intervals down one side. Pipes for this purpose may be purchased already prepared. A head-pipe long enough to extend across the bed, and with 3-inch nipples at intervals for connecting up the steam-pipes, must also be secured.

These pipes are buried with the holes downward, in trenches a foot deep and from 12 to 18 inches apart. Boards, burlap, or canvas are laid over the ground to prevent too rapid escape of steam. The steam is turned on and pressure continued until a soil temperature of 140° F. has been maintained for one to two hours. This can be measured by thermometers buried at intervals, or by the cooking of the potato tuber, as mentioned in the discussion of the preceding system.

The amount of pipe which can be buried and maintained under this system depends on the size of the boiler. If two or more sets of head-pipes and steam-pipes are available, one set can cool and be moved while the other is being used.

The steam-rake

The steam-rake consists of a framework made of hollow steam-pipes, to which are attached teeth made of 8- to 12-inch hollow tubes, with small openings in the bottom. These teeth are 12 to 15 inches apart. The contrivance has somewhat the appearance of a giant spike-tooth harrow.

The teeth are forced down into the ground, and the steam turned on until soil temperatures of over 140° have been maintained for an hour or more. This method is not as convenient as the inverted pan system, and much steam escapes up along the sides of the teeth.

Drain-tile [1] (Figs. 58, 59)

This method of steam sterilization is becoming more popular each year. Steam is turned directly into permanently laid tile drains, eliminating the large force of labor necessary to lay or move the other steam sterilization equipment, and making it unnecessary to work in the greenhouses while the very high temperatures engendered by the escaping steam prevail. The drains are useful in removing excess water, in subirrigation and occasionally in washing from the soil certain soluble salts that might not be desirable for the next crop. An important advantage of this system is that there is no necessity for handling or tramping on the soil after sterilization, thus reducing the danger of reinfecting it with noxious organisms.

Clay or cement common drain-tiles, 2½ inches or more in size, are suitable for this purpose. Special tiles having perforations for the escape of steam are on the market, but these are not essential. Trenches 15 or 18 inches in depth and 12 to 18 apart are dug and the tile laid end to end as for a drainage system.

In greenhouses the tile can be laid either across the house or down the length. If the boiler is of sufficient size to allow for the sterilization of an entire section of a greenhouse at one time, it will probably be most convenient to lay the drains down the length of the house. In a large house it may be more convenient to lay the drains across. Under any circumstances the tiles should be laid under the entire surface so that all the soil will be sterilized, thus reducing the chance of reinfection when walking around in the house.

. To save pipe the steam may be conveyed to the drains through one of the heating pipes in the house. Take-offs may be attached to this pipe, and a short branch pipe dropped down to each string of tiles. Frequent valves will be needed so that the steam can be directed into the number of lines

[1] Brown, H. D., Baldwin, I. L., and Connor, S. D., Greenhouse Soil Sterilization, Ind. (Purdue) Agr. Exp. Sta. Bull. 266. 1922.

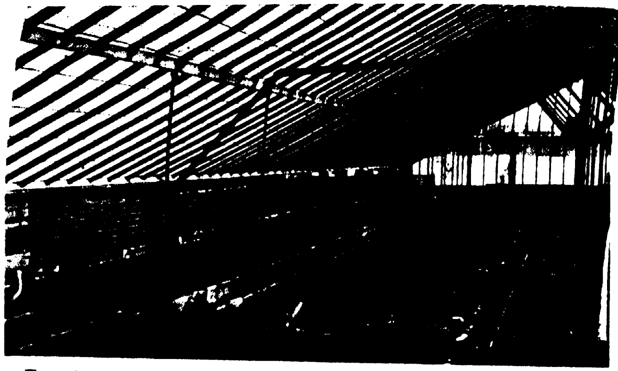


FIG. 58.—Soil sterilization by drain-tile method. When head of steam is insufficient to sterilize entire bed, steam-pipes are connected in the middle of the bed, and a part done at a time.

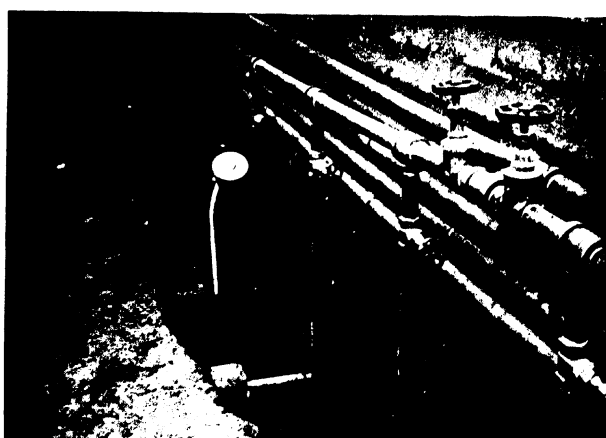


FIG. 59.—Sterilization by drain-tiles, which are connected with the steam-pipes.

corresponding to the capacity of the boiler. In connecting the pipes with the tile, the pipe should extend several feet into the tile. When ready to operate, the soil should be spaded up, smoothed, and covered with boards, straw mats, roofing paper, or burlap, as these will help retain the heat. The ventilators and doors should be closed. The duration of the operation will depend on temperatures maintained. The test of placing a potato in the soil and steaming until this is cooked is a good one. Usually this will require an hour or more. Chupp[1] states that steaming should be continued until the soil temperature reaches 140° F. and then held at that heat for two hours.

FORMALDEHYDE STERILIZATION

Formaldehyde is an effective agent for soil sterilization and can often be used conveniently where steam treatment would be impossible. One gallon of 40 per cent commercial formaldehyde solution is diluted with 50 gallons of water, and this is applied to the soil at the rate of 2 quarts to a square foot of seed-bed. A sprinkling can is a convenient method of application. The soil in the seed-bed is spaded up to permit rapid penetration of the liquid, which should be applied slowly enough to permit all of the solution to soak in. The soil should then be covered with burlap or old blankets, to confine the fumes overnight.

After treatment the soil must be aired until every trace of formaldehyde odor has disappeared. This may take ten to fifteen days in retentive soils. The presence of a very small amount of this fumigant in the soil will kill the young seedlings if the beds are sown before the fumes are dissipated.

Formaldehyde treatment is more expensive and less satisfactory than steam sterilization and is only recommended when the latter is impractical.

[1] Chupp, Chas., Manual of Vegetable-Garden Diseases. Macmillan, 1925.

STERILIZATION WITH CARBON DISULFID

This material is of value in treating small areas to rid the soil of insects in the larval or adult stages. It is too expensive to permit of use on a large scale. However, it is excellent for disinfecting potted plants or seed-bed soils, and is therefore of particular value to nurserymen and greenhouse operators.

According to Fleming[1] a desirable method of fumigating potting soils is to distribute 1 pound (13 fluid ounces) in each cubic yard of soil, keeping the soil at a temperature above 50° F. for at least forty-eight hours. To secure uniform diffusion throughout the mass of earth, dosage holes must be carefully located. A convenient method is to place 18 inches of soil in the fumigation box or on the bench and make injection holes 6 inches deep, in rows 12 to 15 inches apart. One and one half ounces of carbon disulfid are placed in each hole, and a new 18-inch layer of earth is laid on top and treated in the same way until the container is filled. This treatment was aimed particularly at the Japanese beetle.

Carbon disulfid emulsion

Lawns and golf greens may be treated with carbon disulfid emulsion.[2] The emulsion is prepared by mixing 1 part by volume of cold-water-soluble resin-fish-oil soap, 3 parts of water and 10 parts of carbon disulfid. The soap and water are agitated until an even mixture is obtained, and the carbon disulfid added and the whole churned until it emulsifies, as indicated by a change in color and a cream-like consistency of the liquid. One quart of the emulsion is mixed with 50 gallons of water and applied to the turf at the rate of 3 pints to each square foot. It is necessary that the turf be maintained in a moist condition for ten days prior to the application of the insecticide.

[1] Fleming, W. E., N. J. Agr. Exp. Sta. Bull. 380. 1923.
[2] Smith, L. B., and Hadley, C. H., U. S. Dept. Agr. Circ. 363. 1926.

The turf should be laid off into large areas (about 1,200 square feet) and the proper amount of emulsion applied to each area, taking care to apply it slowly enough to allow all of the material to soak in. An attachment is on the market which regulates the amount of emulsion introduced into the water stream from a hydrant. This saves laborious hand application and insures even distribution.

Potted plants can be dipped to destroy larvæ in the soil, according to Leach and Johnson.[1] They advise that the pots containing the plants be immersed for fifteen hours in a solution made by diluting 1 fluid ounce of carbon disulfid emulsion with 15 gallons of water.

Carbon disulfid is also a good fumigant for killing ants. Holes 8 to 10 inches apart and of the same depth should be made in the soil, and an ounce of carbon disulfid placed in each hole. One pound to a mound is sufficient for large mounds made by the mound-building ant. The area should then be covered with wet burlap.

STERILIZATION WITH CALCIUM CYANID

A promising use for this relatively new insecticide is soil fumigation. It has been employed with considerable success for destroying wire-worms, chinch-bugs and various kinds of ants in the soil.

Campbell[2] found in California and Washington that 75 per cent of the wire-worms could be killed with 200 pounds to the acre, while Horsfall and Thomas[3] state that wire-worms were successfully controlled with the same material, on an intensive trucking area near Philadelphia.

They planted a bait crop, such as corn, and allowed the wire-worms to collect around the roots, thereafter treating the

[1] Leach, B. R., and Johnson, J. P., U. S. Dept. Agr. Bull. 1332. 1925.

[2] Campbell, R. E., *Jour. Econ. Ent.*, Vol. 17, No. 5, Oct., 1924.

[3] Horsfall, J. L., and Thomas, C. A., *Jour. Econ. Ent.*, Vol. 19, No. 1, 1926.

soil with calcium cyanid in granular form. This so reduced the number of wire-worms as to make their injury negligible on the cash crops which followed the treatment.

The trap crop is planted early and allowed to get a fair start. Calcium cyanid in granular form is then dropped on the soil around the trap crop at the rate of 150 to 250 pounds an acre, and plowed under. Special applicators are on the market, which can be attached to the plow, and these will drop the poison at the desired rate. This kills the wire-worms and many other undesirable insect pests. A few days later the main crop is planted. Nissley, on demonstrations in New Jersey, found that the cost of treating the soil with calcium cyanid at the rate of about an ounce to a square yard, was $51.39 an acre, as compared to $192.80 an acre for carbon disulfid emulsion treatment. The latter, however, was a little more effective, although not enough more to compensate for the greater expenditure.

Calcium cyanid must be applied when no crops are in the ground. Fall applications are not desirable because the worms are too deep in the ground. Spring applications are, therefore, recommended.

Beyer, of the Florida Experiment Station, found calcium cyanid a valuable fumigant for controlling chinch-bugs in St. Augustine lawn grass. The material may be dusted over the grass, at the rate of 50 to 75 pounds an acre, in the heat of a still day, when the grass is perfectly dry. Three or four applications should be made at intervals of two or three days. If the grass is wet, or if heavy applications are made, the calcium cyanid is likely to burn the grass.

HOT WATER STERILIZATION

This method is efficient only when a few small pots are to be sterilized. The difficulty lies in keeping the water hot when dipping the pots of soil with any rapidity. It takes large quantities of hot water to treat many pots. The water is brought

to the boil, and the pots submerged enough to cover the soil, but not enough to allow the soil to wash out in the kettle. Five minutes is sufficient submersion to kill most organisms in small pots but large ones may take a longer time. The soil must be saturated thoroughly with boiling water.

CHAPTER XIII

DIAGNOSING ORCHARD AND GARDEN TROUBLES

CONTROL of insects and diseases affecting orchard and garden crops is materially simplified if the ailments are known and understood. Determination of the exact causal insect or organism is not necessarily essential, providing the nature of the injury is appreciated and the gardener understands in a general way how to combat that form of injury. Some knowledge of the life histories of insects and diseases is highly desirable, so that the grower may be prepared to anticipate the visits of pests and also may be prevented from wasting spray materials by applying remedial measures when it might be too late to accomplish any good. Even without such exact knowledge, the grower is often able to shape his course by observing the nature of the injury, though he may not be entirely familiar with the cause.

Examples of the points brought out in the foregoing paragraph are numerous. If a gardener finds that the leaves on his currant bushes are being eaten off, he may not recognize the insect which is doing the damage, but he appreciates that it is a leaf-eating pest which he has to combat. An arsenical stomach poison should be the first remedy considered, and with this applied he may rest easy. If the melon or pea vines become covered with plant-lice, the remedy, not the kind of louse, is the outstanding problem. Nicotine and soap should be the immediate answer. If late in the summer apples are knotty (Fig. 60) or if peaches or plums are wormy, it is too late for remedial measures that season, and the value of correct diagnosis is to prevent a waste of spray material at that

time and to insure the application of proper preventive sprays the following season.

Therefore, the following discussion is designed to aid the gardener and fruit-grower in distinguishing between the various types of insect injuries and disease pests which may trouble him. Appearance of both foliage and fruit gives important clues in tracing down troubles. The nature of the injury may be noted on the plant, looked up in the key, and finally studied out in the summaries of insect and disease pests for each fruit or vegetable family in the pages following the key.

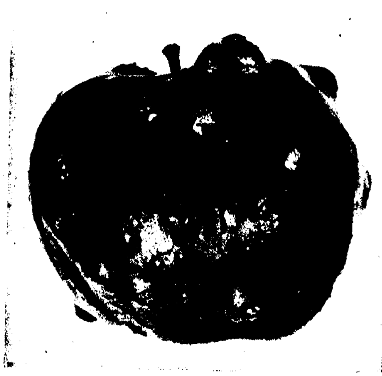


FIG. 60.—Curculio injury on Ben Davis apple.

Plants respond readily to local conditions which control their growth. This response is usually seen plainly in the color and size of the foliage, the rate and total amount of growth, the abundance of crops, and the size of fruit. Though insect and disease pests are responsible for many of the symptoms indicated above, several other factors enter in and may be mistaken by the gardener for ailments caused by pests (Fig. 61). Soil conditions (and the factors under this one heading are legion, including fertility, drainage, depth, moisture content, and many others) can easily cause a yellowish condition of the foliage somewhat similar to that caused by the red-spider or European red-mite, or even leaf-hoppers.

In a general way, the troubles which growers are likely to encounter and associate with insect or disease injury may be

grouped into two main classes: the first including those which are more or less constitutional or organic, affecting practically the entire plant; and the second including those injuries or troubles more restricted in their attack, causing more or less well-defined injured or diseased areas. While these two classes are distinct, it should be taken into consideration that repeated or severe attacks of some troubles of the second class may

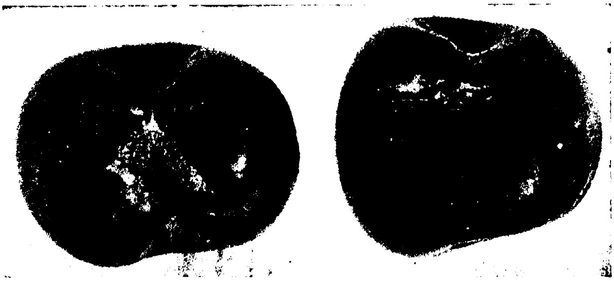


FIG. 61.—Hail-injury on apples, which might be confused with injury made by curculio or some of the worms.

bring about an appearance and condition of the tree that would lead the grower to look for troubles of the first class. However, after careful consideration, few growers would have difficulty in distinguishing between the two main classes. The first group should be canvassed thoroughly to locate the possible source of orchard trouble. If the difficulty is not due to constitutional or organic causes, then the specific insect or disease may be sought in the second group.

CONSTITUTIONAL OR ORGANIC TROUBLES AFFECTING PRACTICALLY THE ENTIRE PLANT

Slow or weak growth of shoots and yellow foliage

Several factors cause weak growth and yellow foliage. Unfavorable soil conditions, such as poor drainage, lack of plant-food, rock or hard-pan near the surface, dry season, girdling,

and winter-injury to the roots are the most important. Poor drainage may be recognized by the presence of standing water, water-loving plants, seepage, or wet springy soils, particularly in wet seasons. Frequently this may be corrected by tile drainage. The presence of rock or hard-pan near the surface may be discovered by the use of a soil augur. Occasionally hardpan may be broken up by subsoiling and by dynamiting. It is a good practice to avoid using these wet or unfavorable soils for cultivated crops.

Poor soils may be built up by the use of cover-crops and manures, or by the addition of nitrogen in the form of nitrate of soda or sulfate of ammonia, potassium in the form of muriate or sulfate of potash, and phosphorus in the form of acid phosphate. Good soils may be deficient in certain elements, but these deficiencies may be made up usually by direct applications. Drought may cause small shoot growth. Irrigation or cultivation, or both, may counteract this trouble. Winter-injury to the roots may be determined usually by digging down to expose them. If the upper roots are dead or weak, while the deeper roots are sound, winter-injury may safely be the diagnosis. Girdling may be the cause of weak shoot growth, but a little excavation around the trunk will enable the grower to tell whether gophers, mice, or rabbits have been at work. If none of these symptoms is present, then insect or disease troubles should be sought.

Die-back

Many of the factors named in the preceding paragraph may be the cause of "die-back," the trouble having become deep-seated enough, or having continued over a sufficient period, to cause the death, through extreme weakening or starvation, of twigs and branches in the more remote parts of the tree. Winter-injury to the tops is a frequent cause of die-back, while in the arid regions where alkali lands abound, this factor occasionally causes the sudden dying of the tops in a season. These general conditions should not be difficult to distinguish, how-

ever, from more local insect and disease injuries such as fire-blight, girdling by borers, mice, brown-rot, or other disease or insect.

Small leaves

Yellows, little-peach, and other diseases are not the only causes of the development of small leaves on trees. Frost-injury in the early spring is a common cause. Leaves so affected are usually somewhat wrinkled, but ordinarily have a normal green color. Lack of available plant-food in the soil is another, but this is usually indicated by pale green foliage. Frost-injury is seldom of much importance and the deficiency in plant-food can generally be corrected by fertilizing.

Pale green foliage

This is usually due to lack of nitrogen, although it may be because of other soil deficiencies. Frequently insects and diseases, when affecting the leaf, leave some definite characteristics quite distinguishable from the pale foliage due to lack of plant-food.

Chlorosis

This term is given to a variety of disorders which are evidenced by a lack of green coloring matter (chlorophyll) in the leaf. The commonest cause is thought to be lack of iron in the soil, while probably the magnesium supply also affects it.

Frenching

Another condition causing foliage peculiarity is called "frenching." Leaves showing this symptom are mottled, having yellow areas between the normally green veins, the leaves being otherwise of normal size and shape. This condition is thought to be due largely to a deficiency of available potassium in the soil. In California "mottle-leaf" is one of the most serious troubles on citrus fruits, and there it is believed to be due to the form in which the nitrogen is available in the soil.

Mosaic and related disorders (Fig. 62)

Most gardeners are familiar with mosaic on raspberries, tomatoes, and melons, and curly-dwarf and spindling-sprout

FIG. 62.—Mosaic disease on leaf of summer squash.

of potatoes. They are characterized by a yellow-and-green mottling of the foliage somewhat as in "frenching," but the leaves are dwarfed, crinkled, or rolled, and the shoots on which these leaves are found are usually somewhat stunted and malformed. These troubles spread rapidly, and the recommendation is immediate removal and destruction of the affected plant as soon as the condition is recognized.

Yellows

Several troubles of this character are familiar to the gardener and fruit-grower, the most common being the "yellows" and "little-peach" of the peach and cabbage and spinach "yellows."

On peach trees frequently only a single limb or branch is affected, but the difficulty usually spreads rapidly through the tree and to near-by trees in the orchard. On vegetable crops these troubles are generally to be identified by a somewhat yellowish sickly foliage which may soon wilt and die. Often it is difficult to distinguish yellows from other troubles.

Dropping off of foliage, blossoms, or partly developed fruit

This condition may be brought about by lack of fertility, dry weather, lack of fertilization of blossoms, natural thinning of the crop, frost-injury, spray-injury (Fig. 63) or combinations of these, as well as by insects and diseases. Failure to secure blossom fertilization is the most common cause, and can be due to lack of congenial pollen or failure of pollen-carrying insects to work during the blossoming season. Cold wet weather frequently keeps insects under cover during the bloom. The planting of self-fertile or inter-fertile varieties is the most satisfactory method of securing pollination. Frost-injury occurs more frequently than many growers realize. The remaining fruit may bear some marks to indicate the trouble, such as regular russet rings or bands around the fruit or about the blossom-end (Fig. 64). These usually have very sharp boundaries or margins, thus distinguishing them from spray russeting or other russeting.

FIG. 63.—Bordeaux mixture spray-injury on apple.

Natural thinning is the effort of the tree to balance the crop with the capacity of the tree. From a commercial standpoint the tree frequently fails to go far enough with the process. As fruit increases in size there is often some dropping due to crowding, some specimens being forced off. Lack of fertility

is a prominent cause of dropping of blossoms from trees in a weakened condition, and nitrogen is again usually the limiting factor. The application of a liberal dosage of nitrate of soda two or three weeks ahead of blooming will often save a part of this drop. Very dry weather occasionally limits the moisture supply so that the tree reduces its transpiration by natural pruning through dropping of leaves. A somewhat constant drop of fruit is sometimes seen throughout a dry summer even on lightly loaded trees, due to dry weather.

Fig. 64.—Frost rings on pears. Note the wide russetted area around the center.

Winter-injury

Troubles arising from this source are usually indicated plainly by certain symptoms, such as the general yellowish weakened appearance of the top which accompanies the death of the roots near the surface of the ground. Other forms of winter-injury may be seen in killing of the twigs, branches, and buds, splitting of the bark (especially on the southeast, south, or southwest side of the trunk or main branches), and injury to the wood in the late fall, or in the spring after the sap has started to flow, such as black-heart. Winter-injury is attributable usually to failure to mature properly in the fall, too cold temperatures in winter, or to the premature starting of growth during mild spells in the winter. Other factors, such

as the amount of moisture in the soil in the fall and winter, the depth of the snow covering, the prevalence of drying winds, also contribute to winter-injury. It is most frequent on poor soils and locations.

SOME ROOT AND TRUNK TROUBLES COMMON TO ALL TREE-FRUITS

Rodent injury

The short-tailed pine mouse, long-tailed meadow mouse, gophers and rabbits attack the roots, crowns or trunks of fruit-trees. Evidences of the rabbit and the long-tailed meadow mouse are easy to obtain and identify, both doing their work above ground, the rabbit stripping the bark from the trunk and leaving ragged edges, while the mouse gnaws the bark away smoothly, leaving teeth marks and smooth margins to distinguish his work from that of the rabbit.

The short-tailed pine mouse and gopher, however, are more insidious in their attacks, burrowing under the ground to girdle the crown or roots, and the first visible evidence noticeable to the grower is the yellow weakened appearance of the top, usually a whole season after the damage has been done. Both leave characteristic teeth marks.

When the tree is not past salvage, bridge-grafting and inarching are remedies. If only the trunk is girdled or badly gnawed, bridge-grafting is usually advisable. When the bark has been stripped from the roots, inarching (the planting of one or more seedling trees around the base of the tree and grafting the top of the seedling into the sound bark above the rodent injury) is more satisfactory.

Field mice may be poisoned by a bait made of rolled oats, beef suet, paraffin, baking soda, and strychnin. The following formula and procedure is recommended by the Federal Bureau of Biological Survey.[1]

"Mix together, dry, ⅛ ounce of powdered strychnin and ⅛ ounce of baking soda. Sift the strychnin-soda mixture over 1 quart of rolled oats, stirring constantly to insure an even

[1] Silver, J., U. S. Dept. Agr. Farmers' Bull. 1397. 1924.

distribution of the poison through the grain. Thoroughly warm the poisoned rolled oats in an oven and sprinkle over them 6 tablespoonfuls of a mixture of 3 parts of melted beef fat and 1 part of melted paraffin, mixing until the oats are evenly coated. When the grain is cool, it is ready for use."

A teaspoonful of this mixture is placed in tiles or wide-mouthed bottles, or covered wooden bait stations, and these are distributed about the orchard. If mice are very abundant, as in a sod orchard, a bait station is placed at the base of every tree.

The pocket gopher is controlled either by poisoning or trapping. According to Dixon,[2] a good poison is made by the following formula:

Sweet potatoes, parsnips, or carrots.........	4 qts.
Flour paste..............................	¼ pt.
Strychnin alkaloid, powdered..............	⅛ oz.
Saccharin	1/32 oz.

The vegetables should be cut into pieces not smaller than three-fourths of an inch, so that the gopher will not be able to pocket or store them but will eat them immediately. The strychnin and saccharin should be stirred into the cooked flour paste and poured over the vegetable cubes, stirring to insure uniform mixture. A pointed steel probe is thrust into the ground at intervals around a gopher exit hole until the main runway is found. One cube is dropped into it and the hole closed with the heel. This operation should be done when the ground is damp, so that the probe can be used. The mounds over the exit holes should be kicked down so that remaining gophers can be located when they make fresh mounds. Specially constructed traps which fit into gopher holes are also used.

Next to extermination, the best protection against rabbit injury is a wire protector extending up along the trunk of a young tree to a height of 24 to 30 inches. Rabbits rarely completely girdle a tree above that point, although when the

[2] Dixon, Jos., Calif. Agr. Exp. Sta. Bull. 340. 1922.

snow is deep they will reach as high as this. One of the best protections is to throw some prunings around the orchard before or during the deep snows. Rabbits will eat the bark off of these first, and may not bother the trees. The use of lime-sulfur sludge, whitewash, or other protective paints is effective if applied frequently, but the benefit is only temporary. Coal tar paints may damage the bark.

FIG. 65.—Crown-gall on apple.

Crown-gall, hairy-root (Fig. 65)

Enlarged irregular corky growths at the crown or on the large roots at the trunk are indications of crown-gall. If the corky growth is covered with fine hair-like roots, it is an indication of hairy-root, a closely related disease. While nurserymen and some growers claim that this disease is not harmful, the best evidence indicates that such trees are usually much weakened as they grow older and come into bearing, probably because of the interference with the sap circulation at the crown. Soft crown-gall, frequently found on branches, is even more detrimental. Plants suffering from this trouble are often shallow rooted and blow over easily or can be swayed by the hand, while yellow foliage is generally another symptom.

Recent work[1] indicates that crown-gall on apple grafts can

[1] Waite, M. B., and Siegler, E. A., *A Method for the Control of Crown-Gall in the Apple Nursery.* U. S. Dept. Agr. Circ. 376. 1926.

be controlled by dipping in a solution of hydroxymercuri-chlorophenol, 1 ounce in 3 gallons of water (1 to 400). Uncut seedlings and cions are dipped for ten minutes before cutting. Newly made grafts are dipped for five seconds. Finally, the grafts are dipped for five seconds just before planting. Grafts should be well fitted and wrapped, and benches and tools disinfected and kept clean. Some losses have occurred when growing conditions were not good following this treatment, but results have been generally satisfactory.

Evidence that crown-gall on other plants may be cured in this manner is lacking. All plants received from the nursery showing this disease, or evidence that it has been cut out before shipment, should be refused. If a shipment is badly infected, the state nursery inspector should be called to inspect the stock.

INJURIES OR TROUBLES MORE RESTRICTED IN THEIR ATTACK

Under this group fall the attacks of the various insects and diseases, which cause well-defined injured or diseased areas or lesions, and which the gardener will combat by such methods as spraying, dusting, fumigation, seed treatment, use of resistant varieties or stocks, and farm practices. When it is certain that no constitutional or organic trouble is the cause of the difficulty, a methodical effort must be made to identify the insect or disease which is at the root of the trouble.

Different insects and diseases attack different plant families. Only rarely does a trouble attack unrelated groups of plants such as the apple and the peach. Very frequently, however, will the same disease or insect be found on several of the species within the same genus. Apple, pear, and quince are affected by the codlin-moth, fire-blight, curculio, and certain of the fruit-worms. Peaches, plums, and apricots are attacked by brown-rot, curculio, and peach root-borers. Therefore, certain hosts may be grouped together according to their susceptibility to attack by pests.

CHAPTER XIV

APPLE PESTS

KEY FOR DIAGNOSING APPLE TROUBLES

If general appearance of the whole plant is merely a pale green, it may be due to lack of nitrogen, iron, or sulfur. (See page 258.)

Foliage yellow

1. Scab—velvety-black slightly raised spots with light-colored margins, these lighter colored margins being due to the pushing up and back of the epidermis.
2. Blotch—if spots are irregular and angular in outline and brown in color.
3. Borers—if pencil-sized holes filled with sawdust are found in the trunk.
4. Cedar-rust—if spots are bright yellow or orange, slightly raised, 1/16 to ¼ inch in diameter, and bearing tuft-like projections.
5. Crown-gall—if base of trunk is enlarged and corky just at or under surface of ground.
6. Scale—small reddish spots of circular outline are likely to be due to scale. If caused by these, a small scale-like insect varying in size from the head of a pin to ⅛ inch in diameter should be found in the center of each spot.
7. Spray-burn or spray-injury—usually confined to limbs or twigs where material has been thrown too forcibly against the foliage, which turns yellow and finally brown, or margins assume a burned dead appearance. Leaf frequently rolls or crinkles.

Foliage eaten

1. Bud-moth—newly unfolding tips in early spring will be tied together in a web by a small brown worm about ⅜ inch long.
2. Climbing cutworms—green, brown, and variegated worms climb trees at night and feed on foliage.
3. Caterpillars—red-humped, if found in July and August and marked with red hump three segments behind the head; yellow-necked, if in July and August and if marked with a yellow collar

just behind the head. Gipsy-moth, found only in New England; tent-caterpillar, if colony of caterpillars spin a web in a crotch near the feeding injury; leaf-roller, if rolled in loose silken web in a leaf; spring or fall canker-worms, if the pests are small green measuring worms which drop down from the tree on a thread when disturbed; tussock-moth, if covered with prominent tufts of white hairs on back; leaf-miner, if tissue between surfaces of leaf is eaten—leaf-skeletonizer, if tissue between veins is eaten, leaving skeleton of leaf; fall webworm, if leaves are skeletonized and whole tips of branch look burned or scorched and are inclosed in a thin web. Due also to lesser caterpillars.

Foliage spotted

1. Scale; scab; blotch (see under *Foliage Yellow*.)
2. Sooty-blotch or sooty-fungus—a black, superficial, unsightly mold develops on the foliage in late summer, being especially prevalent on low ground or in wet seasons. It can be distinguished from other spots by the fact that it can be wiped off with a damp cloth.
3. Cedar-rust (see under *Foliage Yellow*).
4. Spray-injury—copper, sulfur, and arsenical sprays may injure the leaves, causing a spotting which can usually be distinguished from disease by being merely burned or brown spots. Occasionally copper dusts will make tiny black spots.
5. Black-rot and frog-eye—if spots are circular, about ⅛ inch in diameter, and have black margins and grayish centers.

Foliage curled or abnormal

1. Frost-injury—if the first or basal leaves on the twigs or shoots are small and crinkled, with no sign of insect present, the trouble is probably due to frost and is unimportant.
2. Aphis—if wingless insects are on under sides of leaves, causing them to roll or curl.
3. Red-bug—if newly unfolding twig tips are stippled with tiny brownish dots like pin-pricks about blossom time or a few days thereafter.
4. Spray-injury—if leaves are wrinkled and have brown or burned areas on margins.

Foliage white and powdery

1. Powdery-mildew.

Foliage dying

1. Fire-blight—if tips die back in spring and leaves cling to dead branch.
2. Scale (see under *Foliage Yellow*).

Fruit wormy

1. Codlin-moth—if borings are large, extending to seed cavity. Probably 90 per cent of wormy apples are due to codlin-moth.

2. Oriental fruit-moth—if worm like codlin-moth is present but entry hole is difficult to find.

3. Curculio—if seed cavity is eaten out.

4. Maggot—if tiny tunnels and galleries extend through the flesh, with slight depressions and discolorations apparent on the outside.

5. Leaf-roller—if found wrapped up in nest of leaves and surrounded by delicate web.

Fruit knotty and deformed

1. Rosy aphis, red-bug, or curculio.

Surface of fruit stung or eaten

1. Curculio—egg punctures are crescent-shaped, feeding marks are round or irregular, varying in size from ⅛ to ½ inch.

2. Green fruit-worm, Palmer-worm, lesser apple-worm, late brood of leaf-roller—if markings are irregular and large, sometimes extending as a band from ½ to 1 inch in length.

3. Codlin-moth side stings—if the punctures are tiny holes with frass or castings in entrance.

Fruit spotted

1. Scab (see under *Foliage Yellow*).

2. Sooty-blotch (see under *Foliage Spotted*).

3. Blotch—if there are irregular olive-brown blotches, sometimes running together and causing cracking of the fruit.

4. Black-rot—if the spot is at first brown, later turning black, and small black pustules or fruiting bodies, not arranged in concentric circles, arise. Disease usually centers around an injury or skin break.

5. Bitter-rot—if there are circular, brownish-black, rotten spots, on which tiny black pustules appear in concentric rings.

6. Bitter-pit, fruit-spot, stippen, Jonathan-spot, Baldwin-spot —all make considerably sunken round or irregular dark spots extending only a little distance into fruit and generally having a bitter taste.

7. Scale (see under *Foliage Yellow*).

8. Hail-injury—if dents or cuts are found on exposed sides of fruit following hail-storm.

9. Sunburn—if large, round, black or burned spots appear on the cheek upturned to the sunlight after an extremely hot spell.

10. Limb-rub—if fruit rests against a twig or limb, a shiny black blemish occurs on the skin. If leaves constantly whip

against the fruit it will make a network of black or dark brown lines and spots.

Fruit rotting

1. Bitter-rot (see under *Fruit Spotted*).
2. Brown-rot—if spot is soft and decayed, light brown in color, and has powdery mass of brown spores scattered over surface.
3. Soft-rot, blue-mold, pink-rot, spongy dry-rot.

Fruit dropping

1. Worminess; curculio (see under *Fruit Wormy*).
2. Lack of pollination, natural thinning, dry weather.
3. Scab (see under *Foliage Yellow*).

Fruit cracking

1. Scab (see under *Foliage Yellow*).
2. Blotch; hail-injury (see under *Fruit Spotted*).
3. Irregular growth in fall—especially common on some varieties; for example, Stayman.

Fruit watery

1. Water-core.

Limbs and twigs dying-back

1. Fire-blight—may girdle or infect limb or twig; look for signs of canker where diseased and sound wood adjoin. Blighted tissue is bitter to taste and slightly sticky.
2. Bitter-rot—if a black cankered area is noted on limb, with concentric margins and rings of black shiny pustules which have pinkish tips as they fruit.
3. Black-rot—if black cankers appear on the limbs, but without concentric margins and without fruiting bodies.
4. Blister-canker—if there is "shot-hole" effect with hard roundish cores in the holes.
5. Anthracnose—if watery-brown canker appears (usually in fall, on younger branches) ½ to 2 inches in diameter.
6. Winter-injury (see page 261).
7. Sun-scald—if canker is located where direct rays of sun are concentrated on limb through the hot part of day.
8. Collar-rot—may be found at surface of ground. Dead bark there is indication.
9. San José scale (see under *Foliage Yellow*).
10. Blotch—twigs die from being girdled by brown canker with roughened surface, accompanied by blotching of the fruit.

Bark dead

1. Collar-rot; blister-canker; black-rot; bitter-rot; fire-blight; sunscald (see under *Limbs Dying-Black*).
2. Winter-injury (see page 261).
3. Scale (see under *Foliage Yellow*).

Bark girdled (see page 262)

Holes in trunk or branches

1. Woodpeckers—if holes are in even rows around the tree.
2. Blister-canker—if holes have hard core in center and are not arranged in straight lines.
3. Round-headed borers—if holes have sawdust at mouth and go into heartwood.
4. Flat-headed borers—if holes have sawdust and go only under bark.
5. Leopard-moth—if large hole in branches and twigs.
6. Tree-cricket, locust, cicada, tree-hopper, and the like—if long slits are made in bark and wood on small branches and twigs.
7. Twig-borers—if tiny holes are made.

IMPORTANT APPLE PESTS

In general only a few outstanding pests do great damage to the apple. The spray schedule, designed to control these important ones, usually takes care of the hundreds of other insects and diseases of a minor nature which attack this fruit. In other words, as far as the grower is concerned, the minor pests are negligible if the major pests are combated properly.

San José scale, aphis, apple-scab, codlin-moth, and curculio cause great economic losses in every apple-growing region in America. In certain restricted localities, bitter-rot is of major importance, in others anthracnose, and special treatment is essential where such troubles abound. The various caterpillars are pests of great magnitude but are subdued incidental to the control of codlin-moth and curculio; hence seldom have the significance to the grower as do troubles requiring direct treatment. Therefore, from the standpoint of the practical grower and gardener, if the main troubles are understood and correctly treated, he will seldom need to worry further about

pests. Only the principal pests will be discussed in this manual; for further discussion see Manual of Fruit Insects, Slingerland and Crosby, Macmillan, 1914, Manual of Fruit Diseases, Hesler and Whetzel, Macmillan, 1917.

Scab (Figs. 66, 67)

Scab is one of the most general apple diseases. It affects fruit and foliage by making velvety-black slightly raised spots which may grow so numerous as to coalesce and cover an entire large area. On the leaf the spot dies, and an infection on the petiole may cause the leaf to drop. It induces unsightly cracks on the fruit, while an infection on the stem causes much dropping of the fruit in the spring. Some varieties are more susceptible than others. Among the worst are McIntosh, Rome Beauty, Yellow Newton (Albermarle Pippin), Winesap, Stayman, Paragon, and Delicious.

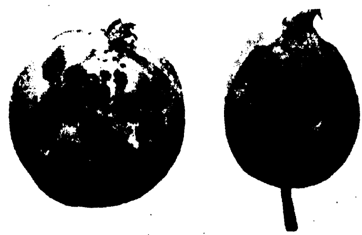


FIG. 66.—Apple scab on young fruits.

Infection is worst in damp, cool, gusty weather with frequent rains. Under such conditions, unless spraying practices are adequate, the entire loss of the crop is frequent. Infection must be prevented, not cured.

Control is secured by coating the fruit and foliage with an effective fungicide, such as concentrated lime-sulfur, bordeaux mixture or other material during the spring and early summer months when wet cool weather is anticipated. When scab is serious, delayed-dormant, pre-pink, and pink-bud sprays are essential. The applications should be made before general storms when possible, so as to have the coating of sulfur or

copper on before the rain, so that the spores of the fungus will not be able to light on uncovered foliage or fruit. Spraying is considered somewhat more effective than dusting for this disease, although control has been secured with dusts by many growers, and also in much experimental work. Possibly the safest method is to apply sprays as far as possible, using the dusting equipment to supplement the spraying. (See spray schedule for apple.)

FIG. 67.—Scab on apple leaf.

Scale: San José, scurfy, oyster-shell, Putman's

The San José scale (Fig. 68) is one of the most important pests of the apple. When conditions favor its development it can become serious enough in one season practically to kill a well-grown apple tree. It is seen on the bark as a small gray waxy cone about the size of the head of a common pin. The bark under it has a bright red appearance when scraped. It makes bright red spots on the fruit. The injury is caused by

the sucking of the juices from the tree. Both scurfy scale and Putman's scale are larger, flatter, and whiter, and do no serious injury. The oyster-shell scale is so called because of the typical shape of its waxy covering. Scurfy and Putman's scale rarely injure plants. Oyster-shell scale is frequently

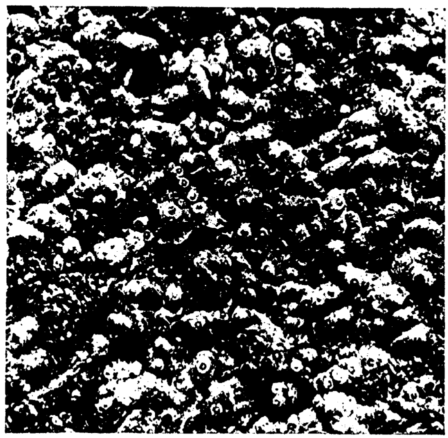


FIG. 68.—San José scale on apple bark. (Much enlarged.)

serious on mock orange, mountain ash, and other trees. Regular annual treatment with concentrated lime-sulfur or oil-emulsion sprays, followed by the application of the regular summer spray schedule, will effectively clean up these scales. Single dormant applications will not control oyster-shell, scurfy, or Putman's scale.

Aphis (Figs. 69-71)

Two species of aphis are important pests of the apple. The rosy aphis has a pinkish or rosy color, and is the one usually

attacking the fruit-clusters in the early spring, sucking the juices from fruit and leaves, curling the leaves, and causing the fruit to become knotty and deformed. The eggs are on the tree over winter, and the best method of control is to spray with either concentrated lime-sulfur diluted 1 to 8 or 3 per cent lubricating-oil emulsion combined with 40 per cent nicotine sulfate, just as the eggs are cracked or hatching, which occurs when the buds start to swell in the spring.

FIG. 59.—Rosy aphis injury on apple.

Green aphis first appear in the early spring, when the oat aphis infest the buds at the time the delayed-dormant spray is applied. These soon disappear without doing any damage, and the real green aphis appear later in the summer on the tips of new foliage, curling the leaves, stunting and deforming the tender shoots, and secreting a honeydew upon which a mold grows that blackens the fruit, leaves, and limbs. Especial damage is done by these green aphis to young trees, which may be much stunted by the attacks. Trees should be sprayed with nicotine sulfate and soap whenever the aphis appear.

Codlin-moth (Fig. 72)

Probably 90 per cent of the wormy apples are due to codlin-moth. When a large burrow partly filled with castings, reaching usually to the seed cavity, is found, this insect is usually to blame. Many wormy apples drop off before maturity, and those that hang ripen prematurely. There are four broods in the warmest southern latitudes, but only one in the most northern districts of New England and Nova Scotia. The Middle Atlantic states, Upper Mississippi Valley, and Pacific Northwest usually have two broods.

FIG. 70.—Aphis eggs on apple twig. (Much enlarged.)

There are three phases of attack which growers must follow to control codlin-moth successfully, the calyx-cup spray, cover sprays, and sanitation. The first two are usually followed in all parts of the United States, and are satisfactory where the insect has not been particularly serious, but where it has gotten beyond control by spraying only rigid sanitary methods will give results. In any case thorough control of the first brood is essential.

Many larvæ enter through the blossom-end of the apple. The blossom-cup must be filled with poison before the calyx closes, in order to get the poison into it. The first brood of

worms usually does not appear until two to five weeks after blossom time. An additional arsenical spray to protect the surface of the fruit is applied at the time this brood appears, and is generally effective in keeping ordinary infestations in check. If later broods emerge cover sprays are applied


FIG. 71.—Green aphis on tip of apple shoot. Note the curled leaves.


FIG. 72.—Apple infested with codlin-moth. Note frass pushed out of larval burrow.

just before the time of emergence. Powdered lead arsenate at the rate of 3 pounds to 100 gallons of spray is recommended.

In districts in which the insect is serious more rigid control measures are essential. R. H. Smith,[1] of the California Agricultural Experiment Station, as a result of investigations from 1920 to 1926, shows that unless the first brood is completely controlled later spraying is relatively ineffective. It has been observed there and elsewhere that the worms will enter apples by boring directly through heavy droplets of poison, and a

[1] Smith, R. H., The Efficacy of Lead Arsenate in Controlling the Codling Moth, Hilgardia, Calif. Agr. Exp. Sta., Vol. I., No. 17, 1926.

small percentage of these escaping where the infestation is severe will produce an overwhelming number of worms for later broods, and these will ruin the maturing apples even though they are covered with a heavy coating of poison. Smith recommends that spraying be supplemented with sanitary measures. Trees should be banded with burlap in late spring, before the worms of the first brood are emerging from the apples to find a place to pupate. Many will pupate under these bands. The bands should be lifted at intervals of ten to fourteen days until harvest time, and the worms killed. Dropped apples should be gathered and destroyed at frequent intervals during the summer. Wormy apples should be picked by thinning crews and saved for destruction. Picking and storage-crates should be disinfected by dipping in boiling water after they have stood filled with fruit for several days. Packing and storage-houses should be located away from the orchard, or disinfected frequently. In the late winter the rough bark on the trunk and large branches of trees should be scraped off.

Spraying for the first brood should be particularly thorough. Smith suggests that two petal-fall sprays and two cover sprays may be applied profitably for this brood under extreme conditions, in order that no surfaces be left uncovered. His work showed that spraying the leaves and twigs was very important. This heavy coating of spray must be maintained on the tree from the time the first brood appears until the last brood is well past. The concentration of powdered lead arsenate may well be raised from 3 to 5 or 6 pounds to 100 gallons of spray. Headlee, of the New Jersey Experiment Station, using the methods outlined by Smith in the Glassboro District in 1926, seemed to secure very promising results under particularly heavy infestation of codlin-moth.

Fruit from orchards receiving heavy spray applications will need to be dipped in dilute hydrochloric acid to remove arsenical residues. (See page 97.)

Curculio (Figs. 73, 74)

The apple curculio is probably of more commercial importance than commonly supposed. It makes ugly russeted somewhat crescent-shaped scars, about the size of the finger-nail and often raised and warty, where feeding punctures were made or where eggs were laid, badly disfiguring the fruit. However, a more serious damage is due to the dropping of small green curculio-stung apples, which may considerably reduce the crop in some years.

FIG. 73.—Egg punctures of curculio on apple.

The insect, a small brown snout-beetle, is difficult to control. It damages the fruit at blossom time and shortly thereafter. It winters over in trash in the orchard, hedgerows, and woodlands. Sanitation measures, such as burning these areas when it can be done without danger to trees, are effective in reducing the insect. Clean cultivation reduces hiding places. The lead arsenate in the petal-fall spray kills many. Sprays should be applied seven and seventeen days after petal-fall where the trouble is severe. When the insects are not particularly numerous, the petal-fall spray and one spray ten to fourteen days following

FIG. 74.—Fall feeding punctures of the plum curculio on apple.

petal-fall will probably be effective. (See spray schedule for apple.)

Caterpillars and canker-worms (Fig. 75)

Small green or greenish-brown measuring worms, which drop down from the leaves on silken threads when disturbed, and

FIG. 75.—Red-hump caterpillar on apple leaf.

tent-caterpillars living in webs in the crotches of limbs, may defoliate limbs or entire trees in the early spring. Later the yellow-necked and red-humped caterpillars, so-called because of characteristic markings just behind the head, cut-worms (thirteen species), webworms, larvæ of gipsy, browntail and tussock-moths and other caterpillars may defoliate the branches. Trees sprayed regularly with $1\frac{1}{2}$ pounds of powdered lead arsenate to 50 gallons of water for budmoth and codlin-moth will not be damaged. Tent-caterpillars and

other colonies of worms may be removed by hand-picking or by flashing with a kerosene torch. Banding with sticky bands or cotton batting will prevent the ascent of cut-worms and the wingless female canker-worm moths.

Green fruit-worm, Palmer worm, case-bearers, leaf-roller (Figs. 76, 77), *white-marked tussock-moth, bud-moth, lesser apple-worm.*

All of these insects make shallow but sometimes extensive feeding injuries on fruit. Usually applications of spray

Fig. 76.—Feeding injury caused by apple leaf-roller larvæ.

materials for codlin-moth (see spray schedule for apple) will control them. Where there is no second brood of codlin-moth, an application of lead arsenate, $1\frac{1}{2}$ pounds to 50 gallons of water, in August may be necessary to prevent late summer injuries.

Red-bug (*false red-bug*) (Figs. 78-80)

Knotty deformed apples are frequently due to the activity of this little bright red insect, which is becoming more widely

distributed, especially in the East. The presence of a definite pit or core, about the size of a pin-prick at the bottom of depressions made by this pest, distinguishes its work from that of the apple aphis, which makes smooth rounded depres-

Fig. 77.—Leaf-roller injury to apple foliage.

sions. This insect has been known completely to ruin an entire crop of fruit. It also stipples with tiny black dots the newly unfolding leaves, causing them to turn yellowish and to curl or wrinkle.

FIG. 78.—Red-bug feeding on young apples.

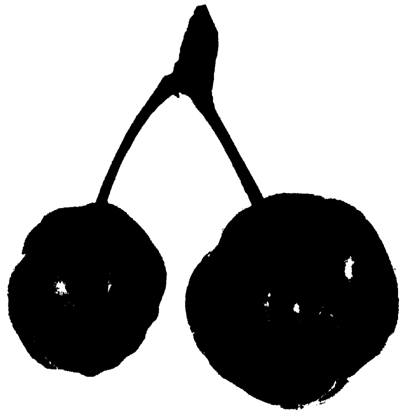


FIG. 79.—Apples deformed by red-bugs. Note the dimpled appearance.

FIG. 80.—Red-bug injury on mature apple leaves. Injury was done when leaves were unfolding.

Control measures consist of either dusting or spraying with nicotine as soon as the insect appears, usually at petal-fall time or shortly thereafter. (See spray schedule for apple.)

Maggot (Figs. 81, 82)

Small, brown, winding tunnels, sometimes reducing the ripening apple to a spongy mass, are due to the work of the apple maggot. Discolored depressions are usually apparent on the surface. Affected apples will not keep. The small blackish fly, appearing about four to six weeks after blossom fall, has peculiar spidery-looking wing markings. As it laps the moisture from the waxed surface of the fruit and foliage, lead arsenate in the first-brood codlin-moth spray (see spray schedule for apple) will usually control it before it lays eggs in the fruit. When serious, one or two accessory sprays may have to be applied at fifteen-day intervals following the first-brood codlin-moth spray. Removal of rotting fruit in the orchard and thorough cultivation under the trees will also help to control this pest.

Bud-moth (*fringed-winged apple bud-moth*)

A small brown worm feeds in the opening buds in the early spring, tieing the leaves together into a rude nest and destroying the blossom buds. In the fall the over-wintering larvæ feed lightly on fruit where a leaf touches and protects them. The damage to buds is frequently very serious. Lead arsenate in the pre-pink and pink-bud sprays (see spray schedule for apple) will usually keep them in check.

European red-mite, clover-mite

These two insects suck the juices from the foliage in the summer, causing the tree to assume a bronzed sickly appearance. Close examination of the leaves will reveal the presence of minute reddish-brown mites on the leaves, which are covered with loose silken threads. In the winter a conspicuous, rusty, reddish appearance is given to areas of the bark where masses of the mites' eggs have been deposited.

Control measures consist in spraying the trees with 3 to 4 per cent lubricating-oil emulsion or with a miscible oil, making the application late in the dormant period.

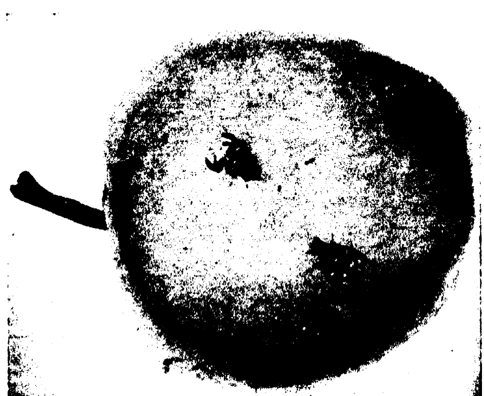


FIG. 81.—Apple maggot flies resting on fruit. Note peculiar markings on wings.

FIG. 82.—Characteristic appearance of apple maggot tunnel as seen through skin of fruit.

Bitter-rot

Bitter-rot, according to Hesler and Whetzel, is unquestionably the most ruinous of all apple diseases in certain years and in certain localities. It makes brownish-black spots on the fruit which merge as they enlarge until the whole fruit may be involved. Decay sets in, and in a few days a fine crop, upon which a large amount of time and money has been spent, is lost. On the diseased spots concentric rings of little black pustules appear which develop a pinkish tip as they fruit, these being a certain means of identifying the disease. The pustules are fruiting bodies from which spores are cast off—to be washed or splashed by rains or dew on to other fruits or limbs, which in turn become affected. On limbs and twigs bitter-rot makes black cankers of various sizes, frequently killing the limb. It does not affect leaves.

When this fungus is most serious, it is controlled by thorough cutting out of cankers in the winter, and applications of 4-4-50 bordeaux mixture through the summer in all regular sprays after the petal-fall, with extra sprays depending on the weather. Bordeaux will russet fruit and burn the foliage in some sections, especially those in which cool moist weather prevails, but the russeting is less damaging than the disease. Lime-sulfur is not effective. (See spray schedule for apple.)

Fire-blight (Figs. 83-85)

This trouble, due to a bacillus, causes limbs and twigs to die-back suddenly, the dead leaves clinging to the wood. Blossoms are blighted in certain years, occasionally resulting in a heavy loss to the crop. Collars and roots are blighted from infections starting on water-sprouts or from wounds caused by cultivation implements, occasionally resulting in the death of the tree.

Cutting out cankers and infected twigs, and disinfecting the wounds, is the only known method of control. Infection is carried by insects which feed on a sticky sweet secretion from

the cankers in the spring, and when they do not secrete this gum by the time the blossoms have fallen there is very little blossom-blight. When the gum exudes before or during blossoming it is carried to the blossoms by insects, and blossom-blight will result. No spraying methods are yet devised to

FIG. 83.—Eradication of fire-blight—the roots after removal of earth.

FIG. 84.—Same tree as Fig. 83 after removal of all blighted bark.

control this trouble, but it can be eradicated by a thorough destruction of cankers on roots and tops of trees during the dormant season.

Blotch

Blotch is one of the most serious diseases of the apple, especially in the Middle West and Southwest and on certain varieties such as Smith Cider, Northwestern Greening, Stark, and Duchess. It makes irregular olive-brown spots which become larger or merge with adjoining spots, finally cracking the apple. Badly affected fruit drops or rots. Leaves, twigs, fruit-spurs, and shoots are also affected.

As infection occurs several weeks before the disease appears,

preventive measures must be applied early. First all cankers on twigs and branches should be cut out. The regular spray schedule (see page 288) will control the disease until after the time of the first-brood codlin-moth spray, which comes three to four weeks after petal-fall. Between this and the second-brood codlin-moth spray, which comes six to eight weeks later, two or three extra fungicidal sprays should be applied. Bordeaux mixture is most effective, but work in Ohio and New Jersey shows that the disease can also be controlled by concentrated lime-sulfur. The lime-sulfur will cause less burning or russeting of fruit and foliage than the bordeaux mixture.

FIG. 85.—Same tree as Fig. 83 after bridge-grafts have been inserted to connect live bark on the trunk with live bark on roots, and the roots thoroughly painted with preservative paint.

Sooty-blotch

A superficial black fungus covers apples in the late summer, detracting greatly from their appearance. It can be wiped off with a damp cloth. It is especially serious in low moist sections or where fogs prevail. The use of lime-sulfur or other fungicide in mid- and late-summer will prevent this disease.

Other apple insects

Many other insects become a menace to the apple industry in certain localities. Leaf-roller is serious in the Northwest and in New York. Round-headed, flat-headed and leopard-moth borers damage the trunks and limbs in many sections. Leaf-hoppers sometimes seriously injure the leaves, and oriental fruit-moth, woolly apple aphis, and fruit and leaf-

GENERAL SPRAYING AND DUSTING SCHEDULE FOR APPLES

	No.	WHEN TO SPRAY	PESTS TO BE COMBATTED	SPRAY MATERIAL TO USE	DUST MATERIAL TO USE	NOTES ON APPLICATION
	1	Dormant spray, before any growth starts in the spring	San José scale, oyster-shell scale, scurfy scale, European red-mite	Conc. lime-sulfur, 1 to 8 of water (Sp. Gr. 1.03), *or* 2% to 4% lubricating oil emulsion, *or* commercial miscible oil diluted according to directions marked on container.	Dusts not satisfactory	Spray either with the wind or all around the tree at one operation. Coat all tips thoroughly. Important when European red-mite is serious.
	**2**	**Delayed-dormant, starting as buds show silvery, finishing before green tips push out like tiny squirrel's ears**	**Scale (as above), European red-mite, aphis, leaf-roller, blister-mite, bud-moth, case-bearer**	**Conc. lime-sulfur, 1 to 8 (Sp. Gr. 1.03), 40% nicotine sulfate solution ½ pint to 50 gals. of spray. Add 1½ lbs. powdered lead arsenate if bud-moth, leaf-roller or case-bearers are present (6%-8% oil spray if leaf-rollers are present).**	**Same as above**	**Spray against the wind, coating the entire tree at one application. Spray thoroughly.**
	3	Pre-pink bud spray, when the blossom-cluster is visible but before blossoms show any color	Apple-scab, bud-moth, fruit-worms, canker-worms, aphis, case-bearers	Conc. lime-sulfur, 1 to 40 (Sp. Gr. 1.008), powdered lead arsenate 1½ lbs. to 50 gals., 40% nicotine sulfate, ½ pt. to 50 gals.	90-10 sulfur-lead arsenate dust. If foliage-eating insects are not present, use dusting sulfur alone. 2% nicotine (5% nicotine sulfate) dust may be applied if aphis are present.	If nicotine has been used in delayed-dormant spray and no aphis are present omit nicotine from this pre-pink spray. Important spray when scab is serious.
	**4**	**Pink-bud spray, when blossom buds show color**	**Apple-scab, mildew, frog-eye bud-moth, canker-worms, fruit-worms, leaf-roller, aphis**	**Conc. lime-sulfur, 1 to 40 (Sp. Gr. 1.008) powdered lead arsenate 1½ lbs. to 50 gals., 40% nicotine sulfate, ½ pt. to 50 gals.**	**90-10 sulfur-lead arsenate dust**	**Spray thoroughly. If aphis have been controlled in preceding sprays, omit nicotine.**
	**5**	**Petal-fall spray, as soon as the petals are about done falling**	**Codlin-moth, curculio, caterpillars, red-bug, aphis, apple-scab, mildew, frog-eye**	**Conc. lime-sulfur, 1 to 50 (Sp. Gr. 1.006), powdered lead arsenate, 1½ lbs. to 50 gals., 40% nicotine sulfate, ½ pt. to 50 gals.**	**80-10-10 sulfur-lead arsenate-lime dust. Apply 1½% nicotine or 3% nicotine sulfate dust in addition if red-bugs are present.**	**Complete this spray within 5 days after petal-fall. If no red-bug or aphis are present omit nicotine spray. Spray very thoroughly.**
	6	7- to 14-day spray (Curculio spray, see note 5.)	Curculio, red-bug, apple-scab, apple-blotch, mildew	Conc. lime-sulfur 1 to 50 (Sp. Gr. 1.006), powdered lead arsenate 1½ lbs. to 50 gals., 40% nicotine sulfate, ½ pt. to 50 gals.	Same as above	Applied where curculio has been serious. If red-bug has been controlled in petal-fall spray, omit nicotine.

	**7**	**1st brood codlin-moth spray, when brood starts to hatch, 3 to 5 weeks after petal fall**	**Codlin-moth, scab, blotch, mildew, bitter-rot, frog-eye, apple-maggot, leaf-hoppers, green aphis,**	**Conc. lime-sulfur 1 to 50 (Sp. Gr. 1.006), or 4-5-50 bordeaux mixture (see note 3), powdered lead arsenate, 1½ lbs. to 50 gals. 40% nicotine sulfate, ½ pt. to 50 gals.**	**nate-lime dust. Satisfactory copper-lime dusts have not been developed. Bordeaux mixture should be applied where bitter-rot, apple-blotch, frog-eye and black-rot are serious.**	**side surfaces of tree. If leaf-hoppers or green aphis are not present, omit the nicotine sulfate.**
	8	About 2 weeks after 1st brood codlin-moth spray	Apple-blotch, scab, bitter-rot, sooty-blotch, Brooks-spot, black-rot, codlin-moth leaf-hopper, green-aphis, apple-maggot	Conc. lime-sulfur 1 to 50 (Sp. Gr. 1.006), powdered lead arsenate 1½ lbs. to 50 gals., 40% nicotine sulfate, ½ pt. to 50 gals. (See note 3.)	Same as above. If leaf-hoppers or green aphis appear a 1½% nicotine or 3% nicotine sulfate dust should also be applied.	This spray is important where bitter-rot and apple-blotch are prevalent. It is also important for codlin-moth where that insect is serious. If no leaf-hoppers or green aphis are present omit nicotine.
	9	About 4 weeks after 1st brood codlin-moth spray	Apple-blotch, scab, bitter-rot, sooty-blotch, Brooks-spot, codlin-moth, leaf-hopper, green-aphis	Conc. lime-sulfur 1 to 50 (Sp. Gr. 1.006), powdered lead arsenate 1½ lbs. to 50 gals. 40% nicotine sulfate, ½ pt. to 50 gals. (See note 3.)	Same as above	Important where bitter-rot and apple-blotch are prevalent. If aphis and leaf-hoppers are not present omit nicotine.
	**10**	**2nd brood codlin-moth spray, 10 to 12 weeks after petal-fall**	**Codlin-moth, apple-blotch, bitter-rot, sooty-blotch, Brooks-spot, yellow-neck and red-hump caterpillars, leaf-hoppers.**	**Conc. lime-sulfur 1 to 50 (Sp. Gr. 1.006), powdered lead arsenate 1½ lbs. to 50 gals. 40% nicotine sulfate, ½ pt. to 50 gals. (See note 3.)**	**Same as above**	**Important where there are two broods of codlin-moth. If more broods, later sprays must be applied at intervals of 2-3 weeks. Maintain a coating of spray. If no leaf-hoppers, omit nicotine.**

NOTES

1. Sprays shown in bold-face type are particularly important in almost every section of the United States. Other sprays are applied when and where necessary. Consult your experiment station.

2. WETTABLE SULFURS can be substituted for concentrated lime-sulfur for summer applications in sections where the concentrated material has caused burning of the fruit and foliage. This is particularly true in the Middle Atlantic states.

3. BORDEAUX MIXTURE may be substituted for concentrated lime-sulfur for summer applications in those sections where it does not cause burning of fruit and foliage, and where such pests as bitter-rot, apple-blotch, and black-rot are serious.

4. DUSTING may be substituted for spraying after the dormant and delayed-dormant sprays, except where bordeaux mixture sprays are necessary for the control of certain diseases. See Chapter IX.

5. Where curculio are serious, spray number 6 is sometimes split into two applications, one coming seven days following petal-fall and the other coming seventeen days after petal-fall.

miners take heavy toll. Descriptions of these may be found in books and bulletins devoted particularly to economic entomology, such as Manual of Fruit Insects, Slingerland and Crosby, Macmillan, 1914.

Other apple diseases

Cedar-rust, causing bright yellow spots on the leaves and yellow pustules on the fruit, is serious particularly in the Middle Atlantic states, and part of the West. Anthracnose, causing cankers on both fruit and branches, is prevalent on certain varieties in the Northwest. Fruit-spot, Brook's-spot, bitter-pit, Baldwin-spot, and Jonathan-spot do great damage in some seasons, and to some varieties. Powdery-mildew is found in New York and the Northwest, especially on Rhode Island Greening, while blister-canker was responsible for a great reduction in Ben Davis and York Imperial trees in the Middle West. In New York and New England and elsewhere black-rot attacks both fruit and limbs, and causes small spots on the leaves. Water-core and internal break-down are physiological troubles prevalent in the Northwest. Brown-rot occasionally becomes of some importance in all sections. Armillaria root-rot, Oozonium root-rot, collar-rot, and other root and trunk infections give trouble in certain districts. These and many other apple pests may be studied in such books as Manual of Fruit Diseases, Hesler and Whetzel, Macmillan, 1917, and in other texts and bulletins.

CHAPTER XV

PEAR AND QUINCE PESTS

KEY FOR DIAGNOSING PEAR AND QUINCE TROUBLES

Foliage yellow

1. San José scale—if red spots develop on foliage, wood, or fruit, and if minute scale-like insects about the size of a pin-head are found in the center of the spots. Some varieties of pears develop red spots on the foliage not due to scale, so scale must be present for certain identification.
2. Psylla—if gummy spots appear on lower surfaces of leaves and these become covered with a sooty mold which spreads over leaves, wood, and fruit, usually with a small nymph in each gummy droplet.
3. Leaf-spot—if brown angular spots with gray centers develop, sometimes merging to involve considerable leaf area.
4. Crown-gall, winter-injury, rodent injury.
5. Leaf-blight—carmine to brown spots develop on leaves and fruit in early spring. Spots are circular with minute black spot in center. Affected young leaves shrivel. Badly affected old leaves drop. Same spots come on fruit, roughening and cracking the skin.

Foliage reddish

1. Unfavorable soil conditions (see page 254).

Foliage blackened and gummy

1. Psylla (see under *Foliage Yellow*).
2. Scab—if no gummy exudation is present and spots are black and velvety and slightly raised.

Foliage skeletonized and blistered

1. Blister-mite—if reddish or greenish-yellow blisters are found with minute whitish mites inside. Blisters later turn brown.
2. Slug—if a tadpole-like slug is eating away the upper surfaces of the leaves.

Foliage spotted

1. Leaf-spot (see under *Foliage Yellow*).
2. Scab (see under *Foliage Blackened*).
3. Rust—if dark brown spots ¼ to ½ inch in diameter with red borders develop, later producing finger-like orange-colored cups in clusters. May be either on leaves or fruit. Is similar to cedar-rust of apple.
4. Red spots for which no apparent insect or disease is the cause develop on certain varieties, especially in dry weather or with a weakened condition of the tree.

Foliage dying or dead

1. Fire-blight—if dying starts at tips and works back or on spurs, and dead leaves cling to the tree.

Foliage eaten

1. Tent-caterpillar—if web is spun in crotch below injured foliage.
2. Slug (see under *Foliage Skeletonized*).
3. Thrips—if dark brown sucking insect rasps opening buds and causes young fruits to fall, especially in the West.
4. Caterpillars—spring canker-worm, if small, slender, green measuring worm is found in early spring and drops down on thread when disturbed; red-humped caterpillar, if third segment behind head is red; yellow-necked caterpillar, if segment immediately behind head is yellow; green fruit-worm, if large and green; Palmer worm, if small and brown.

Fruit knotty and deformed

1. Aphis—if small green or rosy-colored plant-lice are found in clusters of leaves and fruit in spring.
2. False tarnished plant-bug—if a small, brown, quick-moving insect is found on leaves and fruit in early spring, making injuries like red-bug on the apple (see apple red-bug).
3. Blister-mite (see under *Foliage Skeletonized*).
4. Curculio: plum, apple, and quince—if a humped snout-beetle ¼ to ⅜ inch long makes more or less crescent-shaped punctures.
5. Green fruit-worms and other caterpillars.
6. Rust (see under *Fruit Spotted*).

Fruit spotted

1. Scale (see under *Foliage Spotted*).
2. Scab, psylla (see under *Foliage Blackened*).
3. Brown-blotch—if spots are large, smooth, and rusty, sometimes merging to cover the entire surface.

4. Sooty-blotch—if coming late in summer and coating the fruit with a mold which can be wiped off with a damp cloth; is bad in wet seasons or damp locations.

5. Leaf-blight (see under *Foliage Yellow*).

6. Limb-rub—if fruit rests against twig or limb, a shiny black injury results. If leaves whip against fruit incessantly, the surface will be marred and disfigured by black lines and spots.

Fruit wormy

1. Midge—if whitish larvæ feed in blossom and young fruit, destroying core and hollowing out irregular cavity. Found only on young fruit.

2. Codlin-moth—if pinkish-white worm about ½ inch long with black head makes sawdust-filled borings around the core and out to the surface. Most wormy pears are due to this pest.

3. Curculio (see under *Fruit Knotty*).

4. Oriental fruit-moth—if worm resembling codlin-moth is present, but no entry hole is easily discernible.

Fruit dropping

1. Worminess (see under *Fruit Wormy*).

2. Scab, psylla (see under *Foliage Blackened*).

3. June drop, lack of pollination, dry weather, poor soil conditions (see pages 254 to 262).

Limbs dying

1. Fire-blight (see under *Foliage Dying*).

2. San José scale, psylla (see under *Foliage Yellow*).

Holes in trunk or branches

1. Borers: sinuate and flat-headed—if holes go under only the bark in trunk.

2. Borers: round-headed—if borers go into wood in trunk.

3. Twig-girdler, twig-pruner, leopard-moth—if holes are in small limbs and twigs.

4. Woodpeckers—if holes are shallow and arranged in even rows.

IMPORTANT PEAR AND QUINCE PESTS

Seven insects and diseases are of particular importance to the pear-grower. They are San José scale, fire-blight, psylla, codlin-moth, blister-mite, thrips, and scab. In controlling these,

the grower is also able to keep down the most troublesome of the minor pests, save possibly the aphis and false tarnished plant-bug which need nicotine for control. San José scale, fire-blight, and codlin-moth have already been discussed in the pages devoted to the apple and need no further attention.

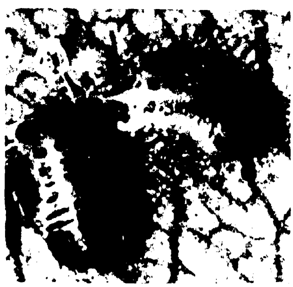


FIG. 86.—Pear psylla nymphs on under side of leaf. Much enlarged.

Psylla (Fig. 86)

In the summer time the leaves become covered with dirty black slimy spots, under which can be seen the nymph of the pear psylla. The leaves yellow and fall. The tree becomes weakened by these nymphs which suck the juices from the leaves, the fruit remains small and drops prematurely, and in severe cases the orchard looks as if it had been swept by fire.

FIG. 87.—Blister-mite injury on pear leaves.

Control is secured by spraying the trees in the first warm sunny days of spring about the end of March, or the last warm sunny days in the fall, perhaps in early December, when the over-wintering adults are out sunning themselves and moving very sluggishly. Two to four per cent oil-emulsion sprays, miscible-oil sprays, or 40 per cent nicotine, 1 pint to 100 gallons of water plus 4 pounds of fish-oil soap, are the best remedies. The tree should be sprayed in one operation. The eggs and newly hatched nymphs can be much reduced by a concentrated lime-sulfur spray when the blossom buds are separated just before bloom. Concentrated lime-sulfur, self-boiled lime-sulfur, wettable sulfurs, or 40 per cent nicotine, 1 pint to 100 gallons of water as above, will kill the nymphs under the drops of honeydew. (See spray schedule for pear.)

Blister-mite (Fig. 87)

Leaves of pears and apples are frequently disfigured by reddish or greenish-yellow blisters, caused by tiny spiders or mites, which work within the tissue of the leaf. Badly infested leaves turn yellow and drop, weakening the tree and stunting the fruit. The dormant or delayed-dormant spray with concentrated lime-sulfur or oil mixtures, readily controls this pest. (See spray schedule for pear.)

Thrips (Fig. 88)

A minute dark brown thrip feeds on the opening buds and leaves of the bud-clusters, rasping the surface and sucking the juices, finally laying eggs in the stems of the young fruit and leaves. The young white thrip feeds on the blossoms and leaves which turn yellow and drop, causing severe reduction and sometimes total loss of the crop, while continued attacks each year weaken the trees and render them more susceptible to disease.

In California, where this insect is most prevalent, control is secured [1] by applying 2½ gallons of either distillate emulsion or a miscible oil, plus ½ pint of 40 per cent nicotine sulfate to 100 gallons of water, just as the buds are opening and again after the petals fall or any time that the insect appears.

FIG. 88.—Thrips injury on pear buds and young shoots.

Scab

This disease, although of the same appearance as apple scab, comes from an entirely different organism. It affects not only fruit and leaves principally, but—unlike apple scab — also the young twigs. It makes velvety lesions which cause dropping of leaves and dropping, cracking, and deformity of fruit. Flemish Beauty, Winter Nelis, Easter Buerré, Duchess, Seckel, and Summer Doyenne are susceptible, while Kieffer is notably resistant.

It is controlled by the cluster-bud, petal-fall, and subsequent sprays. (See spray schedule for pear.)

[1] Horne, W. T., Essig, E. O., and Herms, W. B., Calif. Agr. Exp. Sta. Circ. 265. 1923.

Leaf-spot (Fig. 89)

Defoliation of pear trees in midsummer may be caused by this disease. It weakens the tree and prevents the proper ripening of the fruit and the new wood. The spots which occur on the upper surface of the leaves are recognized by their well-defined angular margins and grayish-white centers. They do not affect the fruit. Bosc, Sheldon, Seckel, Anjou, and Bartlett are susceptible, while Kieffer, Lawrence, and Mt. Vernon are resistant. The petal-fall spray and two additional fungicidal sprays at intervals of two weeks will control leaf-spot. (See spray schedule for pear.)

FIG. 89.—Pear leaf-spot.

Leaf-blight

This fungus causes small circular carmine spots to appear on the leaf in the early spring. These may merge when numerous. When serious, the leaves turn yellow and fall off. The fruit shows the same symptoms, the skin being roughened and frequently cracked. Twigs, petioles, and leaf-scales are also reported to be affected, twigs occasionally being girdled.

The lime-sulfur in the cluster-bud and petal-fall stages and three succeeding sprays will control the disease, especially if iron sulfate is added at the rate of 3 pounds to 50 gallons of spray. If the disease is very serious, it may be necessary to spray every three weeks.

Midge

A minute insect deposits eggs in the opening blossoms, and the tiny white larvæ feed inside the young fruit, completely hollowing it out, stunting and deforming it, and causing much of it to fall. The larvæ mature and pupate close to the surface of the ground. Thorough frequent shallow cultivation in June and July is the most effective method of control, as it destroys the pupæ. No spraying methods are known.

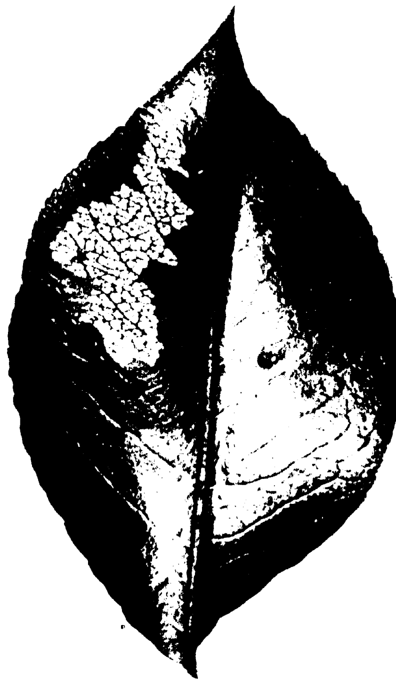


FIG. 90.—Slug at work on pear leaf.

False tarnished plant-bug

Knotty deformed pears with gritty textures have usually been injured by this inconspicuous green insect, which sucks out the juices from the fruit and from the tender newly opening leaves. Nicotine sulfate in the petal-fall spray, or a $1\frac{1}{2}$ to 3 per cent nicotine dust, at that time will usually control them. Careful examination should be made for later injury, however, and if they are present another application should be made. If nicotine sulfate is used alone, 4 pounds of fish-oil soap to 100 gallons of spray should be added.

Slug (Fig. 90)

Small, snail-like, slime-covered slugs feed upon the upper surface of the leaf, skeletonizing it and causing it to fall. Entire trees may be defoliated. Two generations in the North and three farther south have been reported. Lead arsenate is the most practical spray commercially, but dusting leaves with one or two applications of freshly slaked lime will suffice when only a few trees are to be treated. (See spray schedule for pear.)

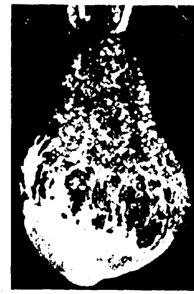


FIG. 91.—Eastern rust on pear.

Curculio

A small snout-beetle, resembling the apple curculio but having no humps, eats holes in the quince fruit, stopping development around the injury and filling the hole with gritty tissue, making the fruit knotty and deformed. Eggs are laid in similar cavities, and the grub, on hatching, burrows around through the flesh of the quince, emerging through a large hole. Spraying with powdered lead arsenate at the rate of 3 pounds to 50 gallons of water, to which has been added 1 pound of calcium caseinate, will somewhat reduce the punctures.

Aphis	(See under Apple, page 273)
Bitter-rot	(See under Apple, page 285)
Bud-moth	(See under Apple, page 283)
Caterpillars	(See under Apple, page 279)
Codlin-moth	(See under Apple, page 275)
European red- and clover-mites	(See under Apple, page 283)
Fire-blight	(See under Apple, page 285)
Green fruit-worms	(See under Apple, page 280)
Rust (pear- or cedar-), Fig. 91..	(See under Apple, page 290)
Scale	(See under Apple, page 272)
Sooty-blotch	(See under Apple, page 287)

GENERAL SPRAYING AND DUSTING SCHEDULE FOR PEAR AND QUINCE

	No.	WHEN TO SPRAY	PESTS TO BE COMBATTED	SPRAY MATERIAL TO USE	DUST MATERIAL TO USE	NOTES ON APPLICATION
	1	Dormant or delayed-dormant	Thrips, scale, blister-mite	Conc. lime-sulfur 1 to 8 (Sp. Gr. 1.03), *or* lubricating oil emulsion 2%, 40% nicotine sulfate, ½ pt. to 50 gals.	Dusts not satisfactory	Omit this application if thrips and scale are neglible factors.
	2	**Cluster-bud, when buds are separated just before bloom**	**Pear psylla, scale, scab,**	**Conc. lime-sulfur 1 to 8 (Sp. Gr. 1.03)**	**Same as above**	**Very important for control of psylla.**
	3	**Petal-fall spray, as soon as the petals are almost all off**	**Codlin-moth, psylla, caterpillars, tarnished plant-bug, scab, aphis, curculio**	**2-4-50 bordeaux mixture or conc. lime-sulfur 1 to 50 (Sp. Gr. 1.006), lead-arsenate powder 1½ lbs. to 50 gals., 40% nicotine sulfate ½ pt. to 50 gals. if psylla become abundant**	**90-10 sulfur-lead arsenate dust. 1½% nicotine, or 3% nicotine sulfate dust may be applied if psylla appear**	**Self-boiled lime-sulfur or wettable sulfur may be substituted for conc. lime-sulfur and bordeaux mixture if these two burn fruit or foliage.**
	4	**7-14 days after petal-fall**	**Curculio, scab, slugs, sooty-blotch**	**Same as above**	**Same as 3**	**Same as above**
	5	**4-5 weeks after petal-fall**	**Psylla, scale, codlin-moth, brown-blotch, sooty-blotch**	**Same as above**	**Same as 3**	**Same as above**

	6 When psylla become abundant	Psylla	2-4-50 bordeaux mixture *or* conc. lime-sulfur 1 to 50 (Sp. Gr. 1.006), 40% nicotine sulfate ½ pt. to 50 gals. if psylla become abundant	2% nicotine or 5% nicotine sulfate dust	Same as above.
	**7 10–12 weeks after petal-fall**	**Codlin-moth, psylla, scab, brown-blotch, sooty-blotch**	**2-4-50 bordeaux mixture *or* conc. lime-sulfur 1 to 50 (Sp. Gr. 1.006) lead-arsenate powder 1½ lbs. to 50 gals., 40% nicotine sulfate ½ pt. to 50 gals. if psylla become abundant**	**Same as 3**	**Same as above**

NOTES

1. Sprays shown in bold-face type are particularly important in most sections of the United States. Other sprays are applied when and where needed. Consult your agricultural experiment station or county agent.

2. When concentrated lime-sulfur burns fruit and foliage, self-boiled lime-sulfur or wettable sulfurs may be substituted.

3. Where anthracnose is bad, as in the Northwest, bordeaux mixture may need to be used in place of concentrated lime-sulfur.

4. Where curculio are abundant, two sprays may need to be applied in place of Spray No. 4, one coming seven days after petal-fall, and the other seventeen days.

5. Where pear psylla are abundant, a lubricating oil emulsion spray may need to be applied, either in the warm days of late November and early December, or during the first warm days in the very early spring, when the over-wintering adult psylla are moving about sluggishly in the sun, and may be hit readily with the spray.

CHAPTER XVI

PEACH AND ALMOND PESTS

KEY FOR DIAGNOSING PEACH AND ALMOND TROUBLES

Foliage yellow

1. Yellows—if foliage is rolled back so that it seems to cling to the branch or twig; if the fruit ripens prematurely and is somewhat misshapen and insipid or bitter; and if tufts of fine, wiry, stunted shoots with light yellow foliage put out from the trunk or main branches.

2. Little-peach—if the foliage shows the same symptoms, but fruit is much undersized and matures later than normal for the variety. No spindling shoot growth accompanies this disease.

3. Borers—masses of sawdust-filled gum around the base of the trunk will identify this pest beyond question.

4. Brown-rot—if depressed, brown, cankered areas are found on twigs.

5. Scale: San José; European fruit lecanium,—if small reddish spots appear on the foliage, twigs, or branches, and a tiny grayish scale insect is in the center of the reddish area.

6. Gummosis—if there is a general gumming of the branches or trunk.

7. Blight—if buds become gummy and die; bark on current year's wood splits; twigs become spotted; and leaves show circular brownish spots with dark red margins.

8. Bacteriosis or black-spot—if leaves show dark brown very angular spots, the centers of which drop out, making shot-hole effect. Fruit also affected.

9. Mildew—if white patches of mycelium develop on lower surface, particularly at midrib, and leaves curl and roll toward midrib.

10. Rosette—if whorls of spindly yellowish sprouts, more tufted and dense than those caused by yellows, develop mostly in the tips of the branches.

Foliage deformed or abnormal

1. Leaf-curl—if the foliage in the early spring becomes thickened, whitish, rolled, curled, and bloated; later dying and dropping.

2. Aphis—if leaves are curled in early spring by yellowish aphis, or in summer by black aphis.

Foliage spotted

1. Blight; bacteriosis or black-spot; mildew; scale (see under *Foliage Yellow*).

2. Scab—if small brown spots develop on those portions of leaf lying midway between main veins, centers drop out leaving circular holes, and fruit is covered with small black spots 1/16 inch in diameter, occasionally so numerous as to run together in a large, blackened, sometimes cracked area.

3. Spray-burn—if foliage is spotted and margins and tips show a burned or brown condition (Fig. 92).

FIG. 92.—Spray-injury on peach leaf.

Foliage dying

1. Leaf-curl (see under *Foliage Deformed*).

2. Oriental fruit-moth—if tips of shoots wither and droop, and a hole can be found in shoot at the tip.

3. Brown-rot—if blossoms have been blasted by the disease, and if cankers with brown depressed margins can be found partially or completely girdling the twigs.

4. Borers; scale; yellows; little-peach; rosette (see under *Foliage Yellow*).

5. Twig-borer—if borer can be found in pith of shoot or twig at base of injured portion.

Foliage eaten

1. Tent-caterpillar—if a web containing caterpillars is formed in a crotch below the injury.

2. Rose-chafer—if reddish-brown beetle ¾ inch long is found feeding.

3. Pear thrips, peach sawfly, striped peach worm.

Fruit rotting

1. Brown-rot—if a small, brown, watery, rotten spot develops, rapidly extending over the peach and later becoming covered with brown powdery spores.

Fruit spotted

1. Scab (see under *Foliage Spotted*).

2. Bacteriosis or black-spot; blight; mildew; scale (see under *Foliage Yellow*).

3. Limb-rub—if fruit rests against twig or limb, a shiny black or brown injury results.

Fruit wormy or gummy

1. Curculio—if gummy exudation on outside of peach marks entry holes of insect.

2. Oriental fruit-moth—if no entry hole can be readily found and tips of new shoots on tree have been killed.

Fruit dropping

1. Curculio (see under *Fruit Wormy*).
2. Oriental fruit-moth (see under *Fruit Wormy*).
3. Brown-rot (see under *Fruit rotting*).
4. June-drop, frost-injury (see page 260).

Surface of fruit stung or eaten

1. Curculio (see under *Fruit Wormy*).

2. Rose-chafer (see under *Foliage Eaten*).

3. Green June-beetle—large velvety-green beetles almost an inch long; mostly in southern states.

Fruit cracked

1. Scab (see under *Foliage Spotted*).
2. Bacteriosis or black-spot; blight (see under *Foliage Yellow*).

Fruit ripening prematurely

1. Yellows (see under *Foliage Yellow*).

Fruit ripening delayed

1. Little-peach (see under *Foliage Yellow*).

Fruit having split stones

1. Usually due to excessive moisture supply and too rapid growth.

Trunk and branches gummy

1. Tree-borer; cankers; brown-rot; bacteriosis; blight (see under *Foliage Yellow*).

2. Borers: shot-hole, pin-hole, twig, lesser peach-tree—if holes are small and in trunk, branches, and twigs.

3. Spray-injury—especially by oils and arsenicals; bark is roughened and scaly.

Holes in trunk or branches

1. Tree-borer—if at base (see under *Foliage Yellow*).

2. Borers: lesser peach-tree, shot-hole, pin-hole, twig—if injury is in tops.

3. Bark-beetles: fruit-tree, peach—if network of burrows is found in or just under bark of weakened trees, and tiny holes 1/16 inch in diameter mark the exits; beetles are about 1/10 inch long and dark brown.

Bark dead

1. Tree-borer; blight; bacteriosis; brown-rot (see under *Foliage Yellow*).

Bark girdled

1. Mice, rabbits, gophers (see page 262).

Bark dead

1. Winter-injury, sun-scald (see page 261).

2. Cankers: blight, bacteriosis, brown-rot, and borers (see under *Foliage Yellow*).

IMPORTANT PEACH AND ALMOND PESTS

Seven major pests annoy the peach-grower, and he must work with greatest zeal to keep ahead of them. They are San José scale, peach tree-borers, peach leaf-curl, brown-rot, scab, yellows, and little-peach. Besides these, bacteriosis, peach blight, aphis, and in some sections oriental fruit-moth are of importance in restricted localities and must be given special treatment, but from the standpoint of the average peach-grower the hundred and one other insects and diseases are controlled by measures exercised for these first seven. Of these the San José scale has been treated during the discussion of the apple. No attempt will be made here to describe all peach pests. Further discussions can be secured from texts and bulletins devoted to economic entomology and plant pathology.

Leaf-curl (Figs. 93, 94)

Puffed-out, puckery, abnormal foliage with a whitish powdery appearance on peach trees in early spring is due to

peach leaf-curl. It is a disastrous disease, sometimes completely defoliating trees in years of severity, causing the fruit to drop or remain undersized. It is very easily controlled by lime-sulfur sprays for scale, or, if scale are not present, by spraying with concentrated lime-sulfur, 1 to 15, or with 4-4-50 bordeaux mixture any time after the leaves fall in October

FIG. 93.—Peach leaf-curl.

until the buds commence to swell in the spring. Applications made after buds begin to swell even slightly cannot be relied on to give control. Oil sprays are ineffective. (See spray schedule for peach.)

Peach tree-borer, prune root-borer (Figs. 95, 96)

A large white grub bores galleries around the base of the trunk and on large roots of the peach tree, causing masses of gum to exude. When the tree is girdled it dies. Hand worming is practiced on one- and two-year-old peach trees, but older trees are treated with paradichlorobenzene, which, when applied around the trunks at the surface of the soil in September or early October and covered with earth, will give better control than hand-working at far less cost and with less damage to the tree. One-fourth to one ounce to a tree, depending on size of trunk, is required. One-fourth ounce is sufficient for a trunk 2 inches in diameter, ½ ounce for a trunk 4 inches in diameter, while 1 ounce will be required on trunks over 8 inches in diameter.

FIG. 94.—Peach leaf-curl. Diseased and healthy shoots.

Yellows (Fig. 97)

When a tree, or even a single branch looks unthrifty, with the leaves becoming leathery and somewhat curled back along the twig, giving the appearance of clinging to it, and the leaves at the base of the twig are small while the terminal leaves are of normal size, when the fruit ripens prematurely, is small, and mottled in color, and insipid or bitter in taste, and finally, when wiry tufts of new growth appear along the trunk or limbs, the tree has yellows. No means of control are known. The tree should be dug out and burned immediately to prevent adjoining trees from becoming infected. It will usually die within a year or so, anyway.

FIG. 95.—Peach tree-borer on young tree (bark cut away, exposing the gallery excavated by the borer).

Little-peach

When the foliage symptoms of yellows are apparent, but are coupled with very small peaches which ripen after the normal ripening date for the variety, and no tufts of wiry growth appear, the tree has little-peach. As with yellows, no control is known. Immediate digging and burning are recommended to prevent the spread of the disease to adjoining trees.

Brown-rot (Figs. 98, 99)

This serious fungous disease attacks blossoms, twigs, limbs, and fruit in all stages of ripeness, sometimes girdling twigs and limbs, blighting blossoms, and causing the loss of an entire crop

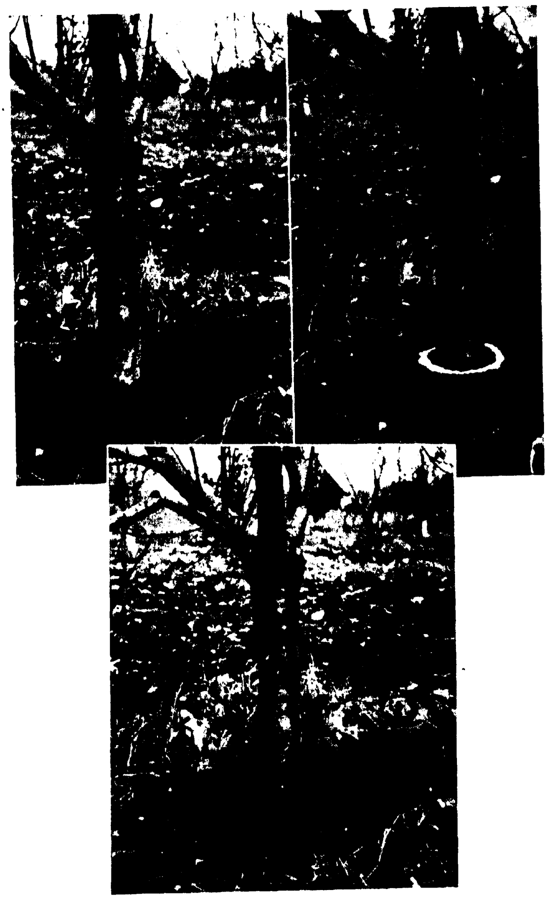


FIG. 96.—Paradichlorobenzene kills peach tree-borers. Top, left, trash removed from trunk; right, paradichlorobenzene applied in a narrow ring an inch away from trunk. Bottom, earth mounded over paradichlorobenzene to hold in the fumes.

FIG. 97.—Yellows on peach limb, indicated by the wiry tufted growth.

FIG. 98.—Brown-rot blossom-blight on peach.

of peaches. The crop must be constantly protected from this disease, from pre-blossom time until the ripe fruit is used, the rot even affecting packed fruit, breaking it down in twelve to twenty-four hours. The larger number of cankers on branches of peach trees are due to brown-rot. The canker is

FIG. 99.—Brown-rot on peach.

a dark roughened lesion with a dead area in the center from which gum usually exudes. The blossom-blight appears during bloom and withers the blossom and leaves a small canker at its base on the twig. On the fruit a small brown spot softens and rapidly spreads until the whole peach is covered. A velvety-brown powdery dust made of the spores appears over the surface. This blows to other fruits, spreading the infection. Dried-up "mummies" on the ground or tree and cankers on the twigs and branches carry the disease over to the next season.

All mummies should be destroyed. Spraying should be done with concentrated lime-sulfur (summer strength) when the

blossoms show color, and with wettable sulfur, or self-boiled lime-sulfur at intervals of every ten days to two weeks until within three weeks of ripening. Dust sprays are satisfactory means of control. A dust applied just before the fruit is to be picked aids in keeping the fruit through packing and shipment. (See spray schedule for peach.)

Plum curculio (Figs. 100, 101)

A snout-beetle makes round feeding punctures or crescent-shaped egg punctures on the peach and plum, causing gum to exude and, in the case of the egg punctures, a wormy peach. Brown-rot frequently obtains entry at these injured spots. The curculio larva can be told from those of the oriental fruit-moth by the entry hole, the latter making a most inconspicuous entry, while the former usually makes a more conspicuous gummy one. The affected fruit usually either falls or rots. An entire crop can be ruined easily in a few days by this insect, unless spraying is prompt and thorough.

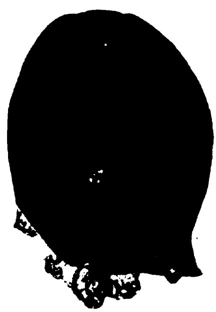


FIG. 100.—Gum exuding from stings of curculio on young peach.

Curculio can be controlled by the application of powdered lead arsenate, 1 pound to 50 gallons of water, when the shucks split, and again ten to fourteen days later. The shuck-split spray should not be delayed until the shucks fall, but should be put on as soon as the shucks have split around the base of the fruit.

Scab (Fig. 102)

Small velvety-black spots appearing on the peach as it ripens are due to scab. When these are numerous the entire surface may be covered, and the fruit cracks and become unsal-

able. Entire crops may be lost by this disease. Sulfur sprays, applied during the summer for brown-rot, readily control this disease. (See spray schedule for peach.)

Black peach aphis (Fig. 103)

This plant-louse may be found at any time of the year in the adult form, on the roots most of the year, but on the tops

FIG. 101.—Jarring the trees to shake off curculio is practiced in the South.

from the time the buds burst until midsummer. Winged forms in midsummer spread the infestation. Forty per cent nicotine sulfate, $\frac{1}{2}$ pint to 50 gallons, included in early spring sprays, will control this pest. (See spray schedule for cherry.) The

chief injury is to roots of one- and two-year-old trees, which may appear to have yellows because of their weakened conditions due to aphis. Growers should not accept nursery stock with aphis on the roots, or, in case the stock is accepted, it should be dipped in a solution of ¾ pint of 40 per cent nicotine sulfate to 50 gallons of water before planting. If aphis are on the roots of growing trees, one should dig away until

FIG. 102.—Peach scab. When scab spots are numerous cracks are frequent.

most of the roots are exposed and sprinkle tobacco dust over them and replace the earth. Then the trees should be fed and cultivated to force a strong growth to enable them to withstand any further aphis attack.

Scale: terrapin, European fruit lecanium (Fig. 104)

These scale secrete a honeydew which serves as a medium for the development of a sooty black mold which renders fruit unsightly. The scale are much larger than San José or scurfy scale and are quite humped and black. Miscible oils or lubricating-oil emulsions are used in the spring as scalecides. Fall applications are dangerous as they frequently injure the buds. Lime-sulfur is not effective against these scale.

FIG. 103.—Black peach aphis.

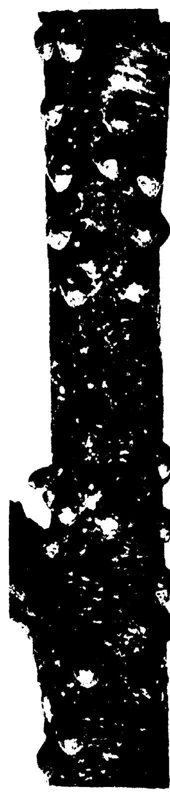


FIG. 104.—Lecanium scale on peach twig.

Black-spot or bacterial shot-hole (Figs. 105, 106)

This disease is of bacterial origin and in midsummer makes ragged spots on the leaves, the dead centers of which fall out leaving an angular hole. Many leaves drop off, impairing the vitality of the tree. Fruit is attacked and is badly disfigured or rendered unfit for sale, large cracks occasionally appearing where the spots are numerous. Ordinary spray mixtures will not control the disease. Anderson [1] reports promising results

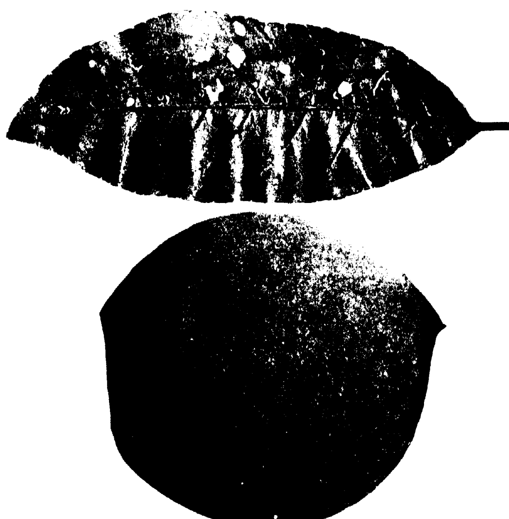


FIG. 105.—Bacterial spot of peach on foliage and fruit.

by spraying with sodium silicoflouride, a material only lately used as a spray, but it is not yet safe to recommend its use, as it burned the foliage. Cankers are sometimes found on the twigs. The removal of cankers is the first step in con-

[1] Anderson, H. W., Amer. Phytopath. Soc., Dec. 31, 1925.

trol. Vigorous trees suffer less than weak ones, therefore building up the vitality of the tree is important.

Blight (*Coryneum-blight*)

This differs from bacterial-blight in that a fungous disease causes the trouble. The effects are shown in the early spring when buds may be killed, green fruiting twigs spotted, leaves dwarfed, and premature defoliation caused. Gum exudes from the affected twigs. On the leaf and fruit the shot-holes are round instead of angular. When several spots merge on the fruit, cracking results. The usual spray schedules for leaf-curl and brown-rot are effective in the spring (see spray schedule for peach), while in California, where brown-rot is not so serious, a bordeaux spray immediately after harvest is recommended. In Oregon the bordeaux spray in the autumn is supplemented by two applications of self-boiled or dry-mix sulfur-lime in the spring after growth starts.

FIG. 106.—Severe case of bacterial spot on peach.

Oriental fruit-moth (Figs. 107, 108)

This is a new and very serious enemy of the peach. It causes countless wormy peaches and kills the tips of the young shoots by feeding in the tender stem. This latter form of injury prevents the sending out of long shoots, dwarfs the tree, and makes the growth bushy. The wormy peaches cannot be identified readily, and they go on the market to the disgust of the housewife, or hasten rot in transit.

FIG. 107.—Shoot injured by the oriental fruit-moth.

Satisfactory methods of control have not yet been worked out. The New Jersey Agricultural Experiment Station recommends late-fall and early-spring cultivation to destroy the tender pupæ, and spraying or dusting with nicotine when the eggs of each brood are being deposited on the under sides of the leaves. The spraying and dusting with nicotine has not proved satisfactory.

FIG. 108.—Oriental fruit-moth injury on fruit.

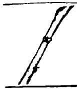
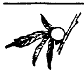
Other peach and almond pests

Bark-beetles and shot-hole borers burrow into the wood on weak trees causing gum to exude. Powdery-mildew makes irregular white blotches on foliage and fruit, sometimes crack-

FIG. 109.—Japanese beetles on ripening peaches.

ing the latter and causing it to fall. Rosette cause whorls of sprouts to form on the twigs. Japanese beetles feed on ripening fruit (Fig. 109), and many other pests attack these hosts. Descriptions may be found in texts devoted specifically to insects and diseases.

GENERAL SPRAYING AND DUSTING SCHEDULE FOR PEACHES

	No.	WHEN TO SPRAY	PESTS TO BE COMBATTED	MATERIAL TO USE	NOTES ON APPLICATION
	**1**	**Dormant spray In spring or fall when trees are entirely dormant**	**Leaf-curl, scale**	Conc. lime-sulfur, 1 to 8 (Sp. Gr. 1.03)	**Spray against the wind so as to coat every portion of the twigs and branches. Lime-sulfur 1 to 15 (Sp. Gr. 1.015) or 4-4-50 bordeaux mixture may be used if no scale are present.**
	2	Pink-bud spray When blossom buds first show pink	Brown-rot blossom blight	Conc. lime-sulfur, 1 to 50 (Sp. Gr. 1.006), or 8-8-50 self-boiled lime-sulfur or wettable sulfurs	This spray may be omitted if brown-rot has not been serious the preceding year. Self-boiled, or wettable sulfur may be used in place of concentrated lime-sulfur.
	**3**	**Shuck-fall spray When the shucks start to fall from young fruits**	**Curculio, brown-rot**	**Self-boiled or wettable sulfurs 8-8-50 or 8-8-½-50, lead-arsenate powder, 1 lb. to 50 gals. or 70-5-25 sulfur-lead arsenate-lime dust**	**Do not delay this spray until shucks are off. Start when shucks are well split.**
	**4**	**10-12 days after shuck-fall**	**Curculio, brown-rot, scab**	**Same**	
	**5**	**3-4 weeks after shuck-fall**	**Brown-rot, scab**	**8-8-50 self-boiled lime-sulfur or 8-4-½-50 wettable sulfur or 80-20 sulfur-lime dust**	**For varieties ripening in Carmen season.**
	6	2 weeks after 5	Brown-rot, scab	Same	For varieties ripening from Carmen to and including Elberta.
	7	3-4 weeks before ripening	Brown-rot, scab	Same	For varieties ripening after Elberta.

NOTES—1. Sprays shown in bold-face type are particularly important in almost every section of the United States. Other sprays are applied when and where necessary. Consult your agricultural experiment station, or county agent.

2. In cooler latitudes and altitudes 80-5-15 and 90-10 dust may be substituted for 70-5-25 and 80-20 dusts.

3. Self-boiled lime-sulfur is a mixture of 8 pounds sulfur, 8 pounds stone lime, and 50 gallons of water, cooked with the heat of the slaking lime. See text.

4. Wettable sulfurs are mechanical mixtures of sulfur and lime, having about 8 pounds of sulfur to 50 gallons of water.

5. Where curculio are particularly serious, as in some sections of the South, it may be necessary to make applications of lead arsenate following harvest. Consult your agricultural experiment station, or county agent.

CHAPTER XVII

PRUNE, PLUM, CHERRY, AND APRICOT PESTS

KEY FOR DIAGNOSING PRUNE, PLUM, CHERRY, AND APRICOT TROUBLES

Foliage yellow

1. San José scale—if leaves or limbs and twigs have reddish spots which extend under the epidermis, with a small gray scale insect about the size of the head of a pin in the center of the red spot.
2. Black-knot—if large blackened irregular swellings are found on twigs and limbs, occasionally killing them.
3. Leaf-spot, leaf-blight, yellow-leaf—if on European varieties, especially in wet seasons, a small circular spot forms, the center falling away leaving a hole; when serious, leaves yellow and fall.
4. Yellows, little-plum, rosette (see under peach).
5. Plum-pockets—if young leaves are yellow, bloated, and curled.

Foliage spotted

1. Leaf-spot or leaf-blight (see under *Foliage Yellow*).
2. Black-spot or bacterial-spot—especially on Japanese varieties, an angular brown spot develops and the center falls away, leaving a shot-hole effect, and fruit shows same spots; when spots are numerous fruit cracks open.
3. Rust—if small yellow spots develop into small, light-brown, round, powdery spots on the lower surfaces of leaves in midsummer.
4. Scale (see under *Foliage Yellow*).
5. Spray-burn.
6. Coryneum fruit-spot—on apricots especially, brown spots appear accompanied by reddish spots, later turning dark green to black on fruit.

Foliage powdery at tips

1. Powdery-mildew.

Foliage deformed and curled

1. Plum-pockets—if leaves are bloated and distorted like peach leaf-curl.

2. Hop plum-louse, mealy plum-louse, rusty and black cherry-aphis—all of these sucking insects may be found curling the leaves and stunting new growth.

Foliage eaten

1. Tent-caterpillars—if web is spun in a crotch below the injured foliage.

2. Plum-gouger—if small snout-beetle with yellow head, thorax, and legs, feeds on foliage early in spring until fruit appears; then goes to fruit where it gouges out pulp through a small hole in the skin.

Fig. 110.—Japanese beetle injury on sour cherry.

3. Other caterpillars, spring and fall canker-worms—if small green worm hangs down from leaves by a thread when disturbed. Tussock-moth, Palmer worm, green fruit-worm, and others are discussed under insects eating foliage of apple.

4. Japanese beetle, if leaves on upper part of tree are skeletonized (Fig. 110).

Foliage dying

1. Plum-wilt—if foliage dies and clings to twigs.
2. San José scale (see under *Foliage Yellow*).

Fruit wormy

1. Curculio—if yellow maggot about ⅜ inch long is found near pit, and crescent-shaped marks are found on fruit.
2. Cherry fruit-fly—if no crescent-shaped marks are found on fruit but worm is present inside near pit.
3. Cherry sawfly—if small white grub feeds on kernel of the pit.
4. Plum-gouger (see under *Foliage Eaten*).
5. Oriental fruit-moth.

Fruit cracked

1. Black-spot (see under *Foliage Spotted*).
2. Rain—if coming when fruit is ripening.

FIG. 111.—Brown-rot on sweet cherries.

Fruit bloated

1. Plum-pockets (see under *Foliage Deformed*).

Fruit rotting

1. Cherry fruit-fly; cherry sawfly; curculio (see under *Fruit Wormy*).

2. Brown-rot—if small, brown, decayed area rapidly spreads to include the whole fruit and brown powdery pustules form on the surface (Fig. 111).

Fruit spotted

1. Scale (see under *Foliage Yellow*).

2. Bacteriosis or black-spot (see under *Foliage Spotted*).

3. Brown-rot (see under *Fruit Rotting*).

4. Coryneum fruit-spot—dark green to black spots are formed on apricots, and these, when numerous, cause fruit to crack. Spots are reddish at first but turn dark later.

5. Scab (see peach scab).

Limbs dying back

1. Scale; black-knot (see under *Foliage Yellow*).

2. Plum-wilt—if a branch or entire tree wilts suddenly during the growing season, and a canker or dead bark is found at base of dead or wilted area.

3. Plum-pockets—if twigs become distorted and swollen and tissues soften and die, but no galls are found.

Limbs or twigs knotty or deformed

1. Black-knot (see under *Foliage Yellow*).

2. Plum-pockets (see under *Limbs Dying Back*).

Limbs or trunks cankered

1. Gummosis—if tree, especially sweet cherry, exudes gum from cankered area on trunk or branches, cankers having a sour odor, usually being formed around the base of twigs or spurs. Several forms of fungi can cause this gum flow.

Trunk and limbs gummy

1. Gummosis (see *Limbs or Trunks Cankered*).

2. Borers: peach-tree, prune-root, twig, round- and flat-headed apple-tree—these are working in galleries on trunk.

3. Winter-injury, poor soil, and the like (see pages 256 to 261).

FIG. 112.—Cherry leaf-spot.

FIG. 113.—Black-knot on plum.

FIG. 114.—Sawfly maggot in cherry.

IMPORTANT PRUNE, PLUM, CHERRY, AND APRICOT PESTS

In this group of fruits, only a few important insects and diseases need occupy the attention of the grower. San José scale, brown-rot, curculio, black-knot, Coryneum-blight, bacterial-spot, leaf-spot and the fruit-flies are the most important. A spray schedule designed to control San José scale, brown-rot, curculio, fruit-flies and leaf-spot will largely control all of the remainder except for the Coryneum-blight on apricots, which requires special bordeaux sprays in the spring and fall, and black-knot of the plum, which requires cutting out and then spraying with bordeaux. San José scale has already been discussed under the apple insects, and brown-rot and curculio under the peach. For descriptions of the many other pests, see books and bulletins devoted to economic entomology and plant pathology.

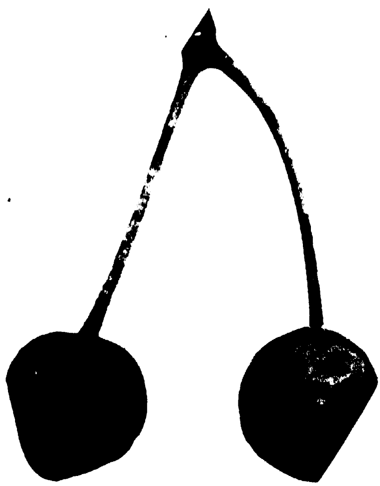


FIG. 115.—Cherries injured by fruit-fly.

Leaf-spot (*leaf-blight, shot-hole*) (Fig. 112)

Dead spots develop on the leaves and the centers fall out, leaving a circular hole. When many holes occur on one leaf, it turns yellow and falls. Trees may be defoliated readily by

this disease, resulting in lack of vigor and poor set of buds for subsequent crops. Lime-sulfur after petal-fall at intervals of two to three weeks will control this disease. (See spray schedule for plum.)

Fig. 116.—Black cherry aphis.

Black-knot (Fig. 113)

The growth of unsightly, black, rough, swollen cankers on limbs and twigs of the plum and cherry is caused by this disease. These cankers may girdle and eventually kill the affected part. The disease has caused the death of some orchards and the abandonment of cherry- or plum-growing in some sections. Control is exceedingly difficult. Cutting out all cankers, regardless of location, in the autumn and early winter before the winter spores have developed, and a spray schedule of three or four lime-sulfur or bordeaux mixture sprays at blossom-fall and thereafter is said to control this disease. Concerted action on the part of all growers in a neighborhood is desirable in controlling this disease. Where it is especially serious, the application of 4-4-50 bordeaux mixture in the early spring, before the buds open, is desirable.

Cherry sawfly (Fig. 114)

In California and Oregon the larva of this insect enters the fruit, eating out the kernel in the pit. The adult lays eggs on the blossom before it opens, and the grub feeds in the fruit until it withers, when it enters another fruit. Satisfactory spraying methods have not been worked out. Thorough deep cultivation of the orchard destroys many cocoons. Early morning spraying with either distillate-oil emulsion or miscible oil and nicotine sulfate as for pear thrips (see page 295) will kill many adults before eggs are laid.

FIG. 117.—Brown-rot on plum.

Cherry fruit-fly (Fig. 115)

A small white maggot in the cherry as it ripens is either due to fruit-fly or curculio. If the affected cherry floats in water, the injury is due to curculio, but if the sound cherries sink it is caused by fruit-fly. In 1923 and 1924 western New York was ravaged by this insect, the federal authorities seizing some of the canned fruit because of the quantities of maggots. So inconspicuous is the entrance of the

fruit-fly larva that its presence is difficult to detect until the housewife opens the cherry.

Control measures are not difficult. Lead arsenate in the petal-fall spray and the sprays coming two and four weeks thereafter will usually suffice to keep the insect in check. (See spray schedule for cherry.)

Cherry and plum plant-lice, and cherry and plum aphis (Fig. 116)

These plant-lice are readily controlled by the application of nicotine sprays in the early spring. The cherry aphis has two to three broods annually, requiring the application of nicotine later in the summer as the additional broods appear.

Bacterial-gummosis

This disease occurs principally in Oregon and Washington at the present time, and practically only on sweet cherries. Damage is especially severe on young trees three to five years old, which may be killed. On old bearing trees the injury is confined more to the twigs and small branches. A flow of gum usually indicates the presence of a canker on the trunk or branch. A sour odor usually accompanies the condition. The canker grows only in winter and early spring. Thus an apparently healthy tree may fail to leaf out in the spring. Removal of the cankers and the use of resistant seedlings, such as Mazzard, are effective, while the growing of resistant varieties may be practiced. No methods of control by spraying are known.

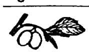
Other prune, plum, cherry, and apricot insects

San José scurfy and oyster-shell scales............	(See under Apple)
European fruit lecanium; terrapin scale..........	(See under Peach)
Green fruit-worms; leaf-roller	(See under Apple)
Peach tree-borer; bark-beetles....................	(See under Peach)
Tent-caterpillar and other caterpillars and cutworms	(See under Apple)
Clover-mite; European red-mite..................	(See under Apple)
Plum-curculio	(See under Peach)

Other prune, plum, cherry, and apricot diseases

Brown-rot (Fig. 117); scab.......................	(See under Peach)
Leaf-spot; black-knot	(See under Plum)
Yellows; little-plum; rosette	(See under Peach)
Crown-gall	(See under Apple)
Bacterial-spot; and Coryneum blight..............	(See under Peach)

GENERAL SPRAYING AND DUSTING SCHEDULE FOR PLUM AND PRUNE

	No.	WHEN TO SPRAY	PESTS TO BE COMBATTED	MATERIAL TO USE	NOTES ON APPLICATION
	1	Dormant-spray As buds are ready to open	San José scale, black-knot, red-mite, twig-miner	Conc. lime-sulfur 1 to 8 (Sp. Gr. 1.03)	If no scale are present this spray may be omitted.
	2	Cluster-bud spray Just before blossoms open	Brown-rot, aphis, curculio, caterpillars, plum-gouger, syneta	Conc. lime-sulfur, 1 to 50 (Sp. Gr. 1.006), powdered lead arsenate 1½ lbs. to 50 gals. or 80-10-10 sulfur-lead arsenate-lime dust. 40% nicotine sulfate, ½ pt. to 50 gals. or a 2% nicotine (5% nicotine sulfate) dust	If no aphis are present, the nicotine may be omitted. 4-4-50 bordeaux mixture may be substituted for conc. lime-sulfur on the Pacific Coast.
	3	Petal-fall spray Immediately after petals have fallen	Brown-rot, leaf-spot, aphis, curculio, caterpillars, plum-gouger	Same	Same
	**4**	**Shuck-fall spray** **When shucks split on young fruit**	**Curculio, brown-rot, leaf-eating insects, leaf-spot**	**Same** **(On Jap. plums use self-boiled lime-sulfur or wettable sulfur)**	**Do not delay this spray until shucks are entirely off. Much curculio injury may result from such a delay.**
	**5**	**2 to 3 weeks after shuck-fall**	**Brown-rot, leaf-spot**	**Conc. lime-sulfur 1 to 50 (Sp. Gr. 1.006) use self-boiled or wettable sulfur on Japanese varieties), or dusting sulfur**	
	**6**	**3 weeks after 5**	**Brown-rot, leaf-spot**	**Same**	

NOTES

1. **Sprays shown in bold-face type are particularly important in almost every section of the United States.** Other sprays may be applied **when and where necessary.** Consult your agricultural experiment station or county agent.

2. Where Japanese varieties of plums, such as Burbank, Red June and Abundance are sprayed, 8-8-50 self-boiled lime-sulfur or wettable **sulfurs having** at least 6 to 8 pounds of sulfur to 50 gallons of water, should be substituted for concentrated lime-sulfur. The Japanese plums **are more tender** than other varieties.

3. The application of sulfur dust a few days previous to ripening will prevent brown-rot during picking and will cause the fruit to carry better in shipping.

GENERAL SPRAYING AND DUSTING FOR CHERRY

	No.	WHEN TO SPRAY	PESTS TO BE COMBATTED	MATERIAL TO USE	NOTES ON APPLICATION
	1	Delayed-dormant As buds separate at tip in early spring	Cherry scale, San José scale, aphids	Conc. lime-sulfur 1 to 8 (Sp. Gr. 1.03), or 2 to 3 % oil spray, and 40 % nicotine sulfate ½ pt. to 50 gals.	Very seldom necessary to apply this spray on sour cherries. If aphids are not troublesome nicotine need not be used.
	2	Cluster-bud spray Just before the blossom buds open	Brown-rot, leaf-spot, curculio, syneta	Conc. lime-sulfur 1 to 50 (Sp. Gr. 1.006) and powdered lead arsenate, 1½ lbs. to 50 gals. or 80-10-10 sulfur-lead arsenate-lime dust	If aphids are not controlled in the delayed-dormant spray, 40 % nicotine sulfate, ½ pt. to 50 gals. may be added to the spray material, or a 2 % nicotine (5 % nicotine sulfate) dust may be used
	3	Petal-fall spray Immediately after petals have fallen	Curculio, brown-rot, leaf-spot, syneta, slugs	Same	If curculio are very abundant it may be necessary to use an 80-20 sulfur-lead arsenate dust.
	**4**	**Shuck-fall spray As shucks are beginning to fall**	**Curculio, brown-rot, leaf-spot, fruit-fly, slugs**	**Same**	**Do not delay this spray until after shucks are off. Apply it when they are well cracked.**
	**5**	**Just before cherries turn red**	**Fruit-fly, brown-rot, leaf-spot, slugs**	**Same**	**Very important spray for control of fruit-fly. Where this pest is absent this spray may be omitted**
	**6**	**Immediately after harvest**	**Leaf-spot**	**Conc. lime-sulfur 1 to 50 (Sp. Gr. 1.006) or sulfur dust**	**Very important in controlling leaf-spot.**
	7	**2 to 3 weeks after harvest**	**Leaf-spot**	**Same as 6**	**Same**
	8	**5 to 6 weeks after harvest**	**Leaf-spot**	**Same**	**Same**

NOTE

1. Sprays shown in bold-face type are particularly important in almost every section of the United States. Other sprays are applied when and where necessary. Consult your agricultural experiment station or county agent.

CHAPTER XVIII

GRAPE PESTS

KEY FOR DIAGNOSING GRAPE TROUBLES

Foliage yellow

1. Dead-arm—if leaves show a yellowing, dwarfing, and curling in midsummer.
2. Root-worm—if in midsummer chains of small, round, contiguous holes are eaten in leaves by little brown beetles, and if roots are badly injured by borers.
3. Cane-borer—difficult to determine without slitting cane at intervals to find borer.
4. Leaf-hopper—if myriads of small yellowish or greenish-white sucking insects are found on lower surfaces of leaves.
5. Overbearing—if vines bore heavily the preceding year and made only a short growth of new wood.

Foliage spotted

1. Black-spot—if spots are reddish-brown and circular with gray centers and appear in midsummer, and fruit develops light colored spot with dark band around it, later becoming depressed and rotting, berry becoming a hard mummy. On canes, small dark cankers form, usually not extending more than one-fourth way around.
2. Downy-mildew—whitish spots appear only on upper surface and become netted with reddish lines, and tissue dies, while canes take on a water-soaked appearance and become dwarfed and whitish. Berries get hard and turn bluish-gray and later become covered with whitish mycelium.
3. Powdery-mildew—yellowish-white spots appear on both surfaces and become covered at once with white felt-like mycelium. Canes are covered with white mycelium and later die, while fruits are dwarfed; some drop, turn dry, and never ripen.
4. Anthracnose—if depressed small bird's-eye cankers form on leaves, canes, shoots, and berries. Spots have light center and dark margins.

Foliage eaten

1. Root-worm beetle (see under *Foliage Yellow*).

2. Flea-beetle—if beetle is small, glossy, greenish-blue, and about 1/5 inch long, and feeds on foliage and buds, while small brown larvæ also feed on them.

3. Rose-chafer—if large yellowish-brown beetle ¾ inch long feeds on foliage and newly formed fruit in June.

4. Berry-moth—if little flap of grape leaf is rolled over to cover a cocoon.

5. Cutworms, army-worms, caterpillars.

Foliage blistered and galled

1. Phylloxera—if small green galls are formed on leaves.

2. Berry-moth (see under *Foliage Yellow*).

3. Erinose—if swellings are found between larger veins on European varieties in California. Galled area is covered with a heavy felt-like covering.

Fruit spotted

1. Anthracnose; black-rot; downy-mildew; powdery-mildew (see under *Foliage Spotted*).

2. Berry-moth—in late summer, caterpillars of this insect sting grape berries, making a spot which enlarges, decays, and envelops the entire fruit.

Fruit stung or wormy

1. Berry-moth; rose-chafer (see under *Foliage Eaten*).

2. Flea-beetle (see under *Foliage Eaten*). Feeds on young fruit also.

3. Curculio—if berry contains a tiny white grub, feeding on seeds and pulp in late June (Fig. 118).

Fruit rotting

1. Berry-moth (see under *Foliage Eaten*).

2. Curculio (see under *Fruit Stung or Wormy*).

3. Black-rot; mildew (see under *Foliage Spotted*).

4. Dead-arm (see under *Foliage Yellow*).

Fruit hard and white

1. Mildew (see under *Foliage Spotted*).

Canes cankered or dying

1. Anthracnose; black-rot; mildew (see under *Foliage Spotted*).

2. Dead-arm; cane-borer (see under *Foliage Yellow*).

3. Cane-girdler—if girdled area can be found at base of injured portion of cane.
7. Root-worm (see under *Foliage Yellow*).

Arms and trunk dying

1. Dead-arm; root-worm (see under *Foliage Yellow*).

Roots dead

1. Root-worm (see under *Foliage Yellow*).
2. Grape-vine root-borers—if borer hollows out the wood and inner bark from roots, leaving outer bark intact. It is $1\frac{1}{4}$ inches long when grown.
3. Phylloxera—if tiny, yellowish, wingless lice infest the roots, and leaves on adjoining vines are blistered by small green galls.

IMPORTANT GRAPE PESTS

Fortunately this imposing array of grape pests can be controlled readily with from five to seven applications of spray, bordeaux mixture, lead arsenate, and nicotine being the materials most used. Powdery-mildew needs sulfur sprays.

Fig. 118.—Curculio in cavity of grape.

The berry-moth, root-worm, flea-beetle, black-rot, mildews, and leaf-hopper are the most important pests. Sprays which will control them will generally keep the others in check.

Berry-moth (Figs. 119, 120)

This insect causes most of the wormy grapes, sometimes infesting from 50 to 90 per cent of the berries. The young caterpillars hatch out as the blossom-buds

are forming, and they feed in the blossom-cluster through the blooming period and until the grapes are fairly well formed. When grown they are dark green to purple. They pupate in flaps in the leaves, rolling up in the flap and spinning a cocoon. The second brood of larvæ feeds ravenously on the green grapes, living inside the berries, making purplish spots on the green berry and often causing it to crack or rot. The third brood comes out in warm sections, infesting the ripening grapes. Lead arsenate in the regular spray schedule will control it effectively. (See spray schedule for grape.)

FIG. 119.—Grape leaf showing the cocoons of the berry-moth larvæ folded in small portions of leaf.

Grape-vine flea-beetle (Fig. 121)

This shiny greenish-blue beetle eats the bud clusters during the warm part of the day, destroying the crop in the early spring. Several weeks later the dark brown grubs of the beetle eat holes in the leaves for two or three weeks, pupating in the ground. Two weeks later, beetles appear again to work on the foliage until they go into hibernation. They are most prevalent near woodlands and hedgerows.

Spraying with lead arsenate and bordeaux mixture as recommended in the spray schedule will control them easily.

FIG. 120.—Berry-moth injury to cluster of grapes.

(See spray schedule for grape.) Cleaning up hedgerows and woodlands is desirable.

Root-worm (Fig. 122)

The larvæ feed on the roots of the grape, devouring the smaller ones and stripping the bark from the main roots,

causing the plant to assume a stunted appearance, and eventually, in some cases, to die. The adults feed on the foliage in midsummer, making characteristic connected rows of round punctures. The damage is mostly done by the time the injury is noted.

Control is effected by spraying the foliage with lead arsenate when the beetles appear on it. The roots of sickly plants

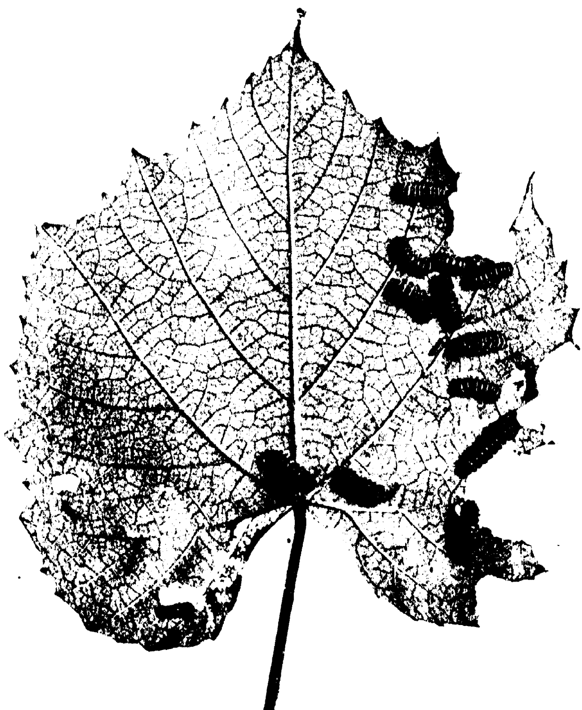


FIG. 121.—Grubs of grape-vine flea-beetle feeding on leaf.

FIG. 122.—Grape root-worm injury.

should be examined for evidences of root-worm. Severe pruning and thorough cultivation and the application of nitrate of soda may bring the injured plants into vigor.

Leaf-hopper (Fig. 123)

Small white wingless insects appear on the under sides of grape leaves in the early summer and suck the juices, causing them to become pale and yellowish. They grow rapidly to a winged jumping form and multiply with great rapidity. Badly infested leaves turn brown and drop off. The fruit does not ripen properly. The infestation may last from early summer until fall.

The nymphs can very easily be controlled by spraying the under sides of the leaves with ½ pint of 40 per cent nicotine sulfate and 2 or 3 pounds of potash-fish-oil soap to 50 gallons of water. The spray must be directed upwards to hit the under sides of the leaves. Dusting with 3 per cent nicotine dust on a warm still day is very effective even against the winged adults. Cleaning up hedgerows and woodlands is desirable.

Black-rot (Fig. 124)

Rotting of grapes when about one-half grown, the spotting of leaves with reddish-brown circular spots, and the formation of cankers on stems, petioles, and canes are frequently due to

FIG. 123.—Grape leaf-hopper. *a*, characteristic mottled appearance of injured leaf; *b*. adult leaf-hoppers; *c*. nymphal stage, when the leaf-hopper cannot fly.

this trouble. Control is effected by spraying the entire vine with bordeaux mixture about the time the second or third leaf is showing, before blossoms open, after blossoms fall, and two or three additional times at intervals of ten days to two weeks, depending on the weather. All mummies and infected canes should be removed and the vineyard plowed in early spring to bury infected leaves and mummies.

Downy-mildew, powdery-mildew

When a yellowish-green or greenish-white mildew causes the berries to shell off, rot, or become mummified, the foliage to be spotted and to fall off, and the canes to be dwarfed or killed, downy-mildew is usually the cause. The velvety felt-like mass of mycelium covers the leaves, cane tips, and fruit. The powdery-mildew makes a lighter colored mycelium, or growth, than the downy-mildew. Five to six applications of 5-5-50 bordeaux mixture, starting as the bud clusters begin to appear and continuing at intervals of ten to fourteen days, will control these mildews. Powdery-mildew on European grapes in California or in the East may be best controlled by sulfur-dust applications made at the same periods.

FIG. 124.—Black-rot of grapes.

Rose-chafer, vine-chafer (Fig. 125)

These ungainly grayish-brown beetles, about ¾ inch in length, eat buds, blossoms, newly set fruit, and foliage of the grape in the early spring. Sandy regions are more favored than districts with stiffer soils. Wettable sulfurs and self-boiled lime-sulfur are excellent repellents. The inclusion of powdered lead arsenate at the rate of 2 pounds to 50 gallons of water, sweetened with 2 or 3 gallons of crude molasses, will kill a great many. Application should be made when the rose-chafers appear.

Other grape insects

Phylloxera (Fig. 126), a louse attacking roots and leaves, making prominent characteristic greenish galls on the latter,

and occasionally killing the roots, cannot be controlled by spraying, but by use of such resistant roots as *Vitis riparia* and *V. rupestris*.

Curculio feed on foliage and lay eggs in the berries, making them wormy. Leaf-folder larvæ feed on the leaves and blossoms, rolling up the edges of leaves for shelter. The cane-borer feeds in the pithy portion of the cane, causing it to wilt and die. The plume-moth feeds on the expanding tips of shoots, webbing the tip leaves into a knot. These and many more insects attack the grape, but with few exceptions, such as the cane-borer, are controlled by lead arsenate, as applied for flea-beetle, root-worm and berry-moth. Other insects are leaf-skeletonizer, cut-worms, cane-girdler, blossom-midge, root-borer and saw-fly.

Fig. 125.—Rose-chafers feeding on clusters of grape blossoms.

Other grape diseases

Anthracnose makes small brown depressed cankers on the shoots and leaves, and dark spots with grayish centers on the berries. Dead-arm causes whole arms to wilt and die, a dry-rot appearing in the wood. Ripe-rot attacks the berries; white-rot the stems of the berries and the leaves and shoots. These are controlled by sprays for black-rot and mildew. Shelling,

brunissure, and California vine-disease are occasionally troublesome, but are little understood. Crown-gall is some-

FIG. 126.—Phylloxera galls on grape leaf.

times found on the roots of nursery stock, and plants troubled with it should be destroyed.

GENERAL SPRAYING AND DUSTING SCHEDULE FOR GRAPES

	No.	WHEN TO SPRAY	PESTS TO BE COMBATTED	MATERIAL TO USE	NOTES ON APPLICATION
	1	Dormant-spray, before growth starts in the spring	Anthracnose, San José scale, grape scale	Conc. lime-sulfur 1 to 8 (Sp. Gr. 1.03)	When scale and anthracnose are not present or dangerous, this spray may be omitted.
	**2**	**When shoots are 4 to 6 inches long**	**Black-rot, anthracnose, mildew, dead-arm, flea-beetle, rose-chafer**	**5-5-50 bordeaux mixture plus powdered lead arsenate 1 ½ lbs. to 50 gals.**	**Spray ENTIRE VINE for control of black-rot.**
	**3**	**As bud clusters appear**	**Anthracnose, downy-mildew, flea-beetle**	**Same**	
	**4**	**When blossoms have fallen**	**Black-rot, anthracnose, mildew, flea-beetle, berry-moth, rose-chafer**	**Same**	
	5	10 to 14 days later	Same	Same	
	6	10 to 14 days after 5	Black-rot, mildew, grape rootworm, flea-beetle, leaf-hoppers	4-4-50 bordeaux mixture, powdered lead arsenate 1 ½ lbs. to 50 gals. 40% nicotine sulfate ½ pt. to 50 gals.	If leaf-hoppers are not present omit nicotine sulfate.
	7 and 8	Depending on weather **and pests**	**Same**	Same	Where fungous diseases and grape rootworm, flea-beetles or leaf-hoppers have been present, or appear, or if the weather continues damp, two or three additional applications must be made. Ripe-rot, berry-moth and flea-beetles and leaf-hoppers sometimes attack the vine late in the season if sprays are not applied.

NOTES—1. **Sprays shown in bold-face type are important in almost every section of the United States. Other sprays are applied when and where necessary. Consult your agricultural experiment station or county agent.**
2. **4-3-50 bordeaux mixture is used in the Southeast in applications following No. 3.**

CHAPTER XIX

RASPBERRY, BLACKBERRY, AND DEWBERRY PESTS

KEY FOR DIAGNOSING RASPBERRY, BLACKBERRY, AND DEWBERRY TROUBLES

Foliage yellow

1. Anthracnose—small, purplish, elevated spots, found toward the base of cane, develop grayish centers. Spots run up and down cane, and sometimes coalesce, making blotches; canes sometimes crack; leaves are yellow and dwarfed with whitish blisters; fruit ripens prematurely or dries up.
2. Yellows—if red raspberry plant suddenly becomes sickly, stunted, and bushy with dwarfed, yellowish, mottled foliage and margins of leaves curled downward; and fruit is bitter, light-colored, small, and ripens prematurely.
3. Orange-rust—if fruiting pustules on leaves give off powdery orange-colored spores; leaves are dwarfed and rolled.
4. Red-spider—if tiny reddish mites are found, principally on the under side of leaves.
5. Mosaic, leaf-curl, streak—plants get sickly and foliage is a yellowish streaked color, with deeper green veins; canes are stunted; leaves become curled and rolled.
6. San José scale—if reddish spots on leaves and canes, having grayish scale insect about the size of a pin-head in the center of them, are found.

Foliage spotted

1. Orange-rust; anthracnose; San José scale (see under *Foliage Yellow*).
2. Leaf-spot—brown spots about ⅛ inch in diameter, having whitish centers.
3. Sawfly—eggs are laid between leaf tissues, causing those spots to die, and small green caterpillars hatch out and feed on leaves and fruit.
4. Leaf-miner—tiny larvæ are feeding between leaf surfaces.

Foliage wilting or dying

1. Cane-blight—if single branch of whole cane suddenly dries up with no sign of cane-borer injury.
2. Blue-stem—if blue-black stripe appears on lower part of cane or stem, especially on black-cap raspberries.
3. Anthracnose (see under *Foliage Yellow*).
4. Spur-blight—if sharply defined black cankers from 1 to 4 inches long are found, especially at the nodes on lower part of cane.
5. Cane-borer, cane-maggot, red-necked cane-borer—if burrow of borer is found in pith at base of injury.
6. Horn-tail—if burrow made by insect is spiral-shaped.
7. Crown-borer—if white grub is found at crown.,

Foliage eaten

1. Sawfly; leaf-miner (see under *Foliage Spotted*).
2. Rose-chafer—if large, tan-colored, long-legged beetle feeds on foliage, buds, and fruit.
3. Flea-beetle—if small shiny, blue-green or blue-black beetles feed on leaves and jump when disturbed.
4. Climbing cutworm—if foliage is devoured at night and no caterpillars can be found during the day.

Canes spotted

1. Anthracnose (see under *Foliage Yellow*).
2. Blue-stem; spur-blight (see under *Foliage Wilting or Dying*).

Canes dwarfed or stunted

1. Yellows; anthracnose; orange-rust; mosaic; leaf-curl; streak (see under *Foliage Yellow*).
2. Psyllid—if small, sluggish, brownish louse migrates from near-by pines to blackberry plantation in late spring, sucking juices out of leaves, stunting and curling both leaves and shoots, making foliage darker green than normal.

Fruit eaten

1. Rose-chafer; climbing cutworms (see under *Foliage Eaten*).
2. Sawfly (see under *Foliage Spotted*).

RASPBERRY, BLACKBERRY AND DEWBERRY PESTS

Most of the bramble troubles are controlled by rogueing out the affected canes or plants rather than by spraying. In fact, in most districts no regular spraying is done by the commer-

cial growers, except possibly for the control of special pests such as red-spider or anthracnose. This disease has become so troublesome in many places that efforts are being made to check it by spraying, but notwithstanding the fact that spraying with lime-sulfur is successful in some sections, such as Wisconsin for example, it is not particularly effective in New Jersey.

The brambles have a few pests in common with other plants, such as crown-gall, San José scale, climbing cutworms, rose-chafer, and a few others which have been discussed in preceding pages. There are only four or five other pests of first magnitude that need attention in all parts of the country. They are yellows, anthracnose, orange-rust, cane-blight, and the cane-borers. These are controlled principally by removal of infested plants, by crop rotation, use of disease-free plants, and by cutting out old canes as soon as they have fruited.

Yellows

Stunted, sickly, bushy, yellowish plants, having dwarfed fruit-bearing laterals and abnormally small leaves with margins curling downward, found in red raspberry patches two years old or older, usually are affected with yellows. The berries become dry or ripen prematurely. The plants do not wilt as in the cane-blights or in case of borer injury. The cause is unknown. Spraying is ineffective. Disease-free plants from disease-free sections should be used, and all diseased plants rogued out as they show. St. Regis (Ranere) is resistant. Cuthbert, Marlboro, Golden Queen, Early King, and Herbert are susceptible in the order named, according to Hesler and Whetzel.

Anthracnose (Figs. 127, 128)

Small purplish spots first appear near the tips of the canes of raspberry and blackberry plants and are probably worst on black raspberries. As the spots grow and merge, they form large, irregular, grayish-white slightly raised cankers with

purple margins. The canes become sickly and yellow, frequently cracking, leaves are dwarfed, and fruit dries up. The purple spots develop on the leaves, finally making whitish blisters; the leaf becomes distorted and the edges roll toward

FIG. 127.—Anthracnose on red raspberry.

FIG. 128.—Anthracnose on purple-cane raspberry.

the midrib. The diseased tissues may fall away, leaving a shot-hole effect. If the young canes are not killed the first year, the formation of fruit for the next year is prevented. The disease is worst on black raspberries.

Anthracnose is very difficult to control. Disease-free plants

should be secured. Old canes should be cut from young plant roots at the time of setting out the bed. Weeds and trash should be removed from around the plants during the growing season to aid free air circulation and a lower humidity. All

FIG. 129.—Blackberry psyllid injury.

diseased canes should be burned at the end of the fruiting season. Jones[1] advises the application of 1 to 10 concentrated lime-sulfur after a few leaves have unfolded in the spring, and another application, using 1 to 40 concentrated lime-sulfur, about a week before blooming. This gave excellent results in Wisconsin. The use of 4-4-50 bordeaux mixture applied just before the leaves appear, just after they unfold, when shoots are six inches high, just before fruiting, and per-

[1] Jones, L. K., Wis. Agr. Exp. Sta. Res. Bull. 59. 1924

haps several subsequent applications if the weather is wet, has been advised by some authorities. The beds should be rotated, not allowing the raspberries to fruit after the third crop.

Fig. 130.—Red-spider injury to raspberries.

Orange-rust

Bright-colored orange spots on the surfaces of leaves of blackberries and raspberries appearing in the spring, accompanied by rolling or curling of leaves, exposing the rust pustules, indicate orange-rust. It is one of the most serious diseases of cane-fruits. All affected plants should be destroyed immediately. Spraying is ineffective as far as is known.

Cane-blight

The sudden wilting of canes on raspberry plants, especially fruiting canes, may be due to cane-blight. It can be distinguished from borer injury because there will be no borings or girdlings, on blighted canes. The berries dry up. Spraying remedies are not certain. Crop rotation and planting of disease-free stock are advised. Old canes should be burned. Wilted canes should be removed at once and burned.

Cane-borer, cane-maggot, red-necked cane-borer, horntail

Wilting on tips of raspberry and blackberry canes may be due to the girdling of the beetle of the raspberry cane-borer, after she has deposited an egg in the cane about six inches from the tip, or to the work of the various cane-borers.

These insects are controlled by cutting out all wilting tips as soon as the wilting is perceived. Care should be taken to cut canes below the work of the insect. The removal and the burning of all bearing canes immediately after harvest also aid in control.

FIG. 131.—Raspberry spur-blight.

Psyllid (Fig. 129)

This tiny, brownish, sluggish plant-louse punctures leaves and tender canes and sucks out the juices, causing the leaves to curl and the shoots to coil up and become much distorted. It comes out in the late spring, migrating to the blackberry patch from pines. Foliage on infested canes becomes abnormally dark green in color. Control is secured by spraying with 3/4 pint of 40 per cent nicotine sulfate and 2 pounds of fish-oil soap to 50 gallons of water, or by cutting off the tips of the infested canes shortly after the infestation takes place.

Red-spider (Fig. 130)

Very tiny reddish mites are found on the under sides of the leaves under a delicate silken web, where they feed by sucking

the juices, causing the foliage to yellow and the plants to become sickly. They may be controlled by drenching with a strong stream of water, spraying with wettable sulfur or self-boiled lime-sulfur, or dusting heavily with dusting sulfur.

FIG. 132.—Crown-gall on blackberry.

Sawfly

Tiny eggs laid between the surfaces of the leaves cause them to die at that point and become spotted. Small green larvæ hatch from these eggs and devour the leaves, and then attack young shoots, blossom-buds, and immature fruit. They are controlled by arsenical sprays until ripening approaches, when hellebore is used.

Spur-blight (Fig. 131)

Spots, or cankers, found at the nodes in the lower parts of the canes of black and red raspberries, or on the petioles of the leaves, resulting in the yellowing, falling off, or death of all of the fruit-buds within perhaps two feet of the ground, may be due to this disease. The bark often cracks at these points, allowing canes to dry out, turn yellowish, and become brittle so that they may break when being laid down for the winter. A 3-2-50 bordeaux mixture should be applied to the young canes to prevent infection. Three sprays before and one following picking will usually suffice (see spray schedule for small-fruits), the first one being when the canes are six to ten inches high, and the remaining ones at intervals of two weeks. Old canes are removed and burned immediately after fruiting.

Other raspberry, blackberry, and dewberry pests

San José scale, cutworms, caterpillars, bud-moth	(see Apple, page 272)
Rose-chafer, leaf-hopper	(see Grape, page 340)
European fruit lecanium.......................	(see Peach, page 314)

The crown-borer girdles the plant at the crown, causing it to wilt. Systematic digging out of the pest is the only method of control. Raspberry leaf-roller and raspberry beetle occasionally injure the foliage and may be hand-picked, or sprayed with $1\frac{1}{2}$ pounds of powdered lead arsenate to 50 gallons of water for the leaf-roller, and double that strength for the beetle.

Crown-gall may be found in nursery stock, and in the field. Infected plants should be destroyed (Fig. 132). Blue-stem (curly-leaf), double-blossom, and mosaic are not controlled by spraying, but are checked by using disease-free plants and by rogueing out infected plants from the field. Descriptions of these pests may be found in books devoted to economic entomology and plant pathology.

GENERAL SPRAYING AND DUSTING SCHEDULE FOR RASPBERRY, BLACKBERRY and DEWBERRY

	No.	WHEN TO SPRAY	PESTS TO BE COMBATTED	MATERIAL TO USE	NOTES ON APPLICATION
	1	Dormant-spray, before the leaves appear	Anthracnose cane-blight	4-4-50 bordeaux mixture	If scale are present, substitute conc. lime-sulfur—1 to 9.
	2	When new leaves are unfolding	Anthracnose, cane-blight, leaf-spot, spur-blight, sawfly, leaf-miner, climbing cutworms	Bordeaux mixture 4-4-50 *or* conc. lime-sulfur, 1 to 50 (Sp. Gr. 1.006) plus powdered lead arsenate 1½ lbs. to 50 gals. 40% nicotine sulfate ½ pt. to 50 gals.	If leaf-miner is not serious, and aphis are not present, leave out the nicotine sulfate.
	3	2 weeks after 2	Same	Same	Same
	4	2 weeks after 3	Anthracnose, cane-blight, spur-blight, leaf-spot	4-4-50 bordeaux mixture *or* conc. lime-sulfur, 1 to 50 (Sp. Gr. 1.006)	If aphis are present add nicotine sulfate as in 2. If red-spider are present use lime-sulfur or dusting sulfur. If climbing cutworms or other foliage-eating insects are present add powdered lead arsenate as in 2.
	5	Shortly before ripening	Same	Burgundy mixture (see page 91)	Same
	6	After fruit is harvested	Spur-blight, anthracnose, leaf-spot	4-4-50 bordeaux mixture	If weather remains moist and these diseases have been serious, a subsequent application may be made in 2 weeks.

NOTES

1. Cut off and burn all wilted tips as they appear on the plants, to control various borers.
2. Rogue out and burn all plants showing symptoms of orange-rust, yellows, blue-stem, and cane-blight.
3. Cut out and burn old wood immediately after fruit is harvested.

CHAPTER XX

CURRANT AND GOOSEBERRY PESTS

KEY FOR DIAGNOSING CURRANT AND GOOSEBERRY TROUBLES

Foliage or canes yellow or spotted

1. Leaf-spot—if brown spots about ⅛ inch in diameter appear on both surfaces of leaf; pale center of spot produces small black fruiting bodies; leaves turn yellow and fall prematurely.
2. Anthracnose—if small, dark brown, circular spots appear on upper surfaces of leaves, canes, and fruits. On fruits, they are small black dots resembling fly-specks, and on canes they are ¼ to ½ inch long, half girdling the stem.
3. European rust—if rusty pustules form on both sides of leaves in late spring; when severe, it causes leaves to fall. Also affects white pines.
4. Angular leaf-spot—if pale-colored angular spots appear.
5. Powdery-mildew—if whitish mold appears in spots or patches on leaves and canes, distorting leaves and tips, dwarfing berries, and sometimes cracking and decaying them.
6. Currant-borer (see under *Foliage Wilted and Dying*).
7. Four-lined leaf-bug—if green matter is sucked from leaf, leaving white spots which turn brown; entire leaf may die.

Foliage and canes wilted or dying

1. Cane-blight—if whole or part of plant suddenly wilts and dies, and no evidence of borers in canes or crown can be found.
2. Imported currant-borer—if borer can be found burrowing in pith at base of injury.
3. Stem-girdler—if tips of canes wilt and die from girdling.

Foliage eaten

1. Imported currant-worm—if greenish-black worms feed on foliage.
2. Green currant-worm—if worm is green and smaller than imported currant-worm.
3. Span-worm—if a white span-worm with yellow stripes and black dots.
4. Cutworms, green fruit-worms, pepper-and-salt currant-moth.

Foliage curled or abnormal

1. Aphis (currant plant-louse)—if yellowish-green lice are found on under sides of leaves.

Foliage and fruit white and powdery

1. Powdery-mildew (see under *Foliage Yellow*).

Fruit cracked, eaten, and decayed

1. Gooseberry-midge—if bright yellow maggot is found in decaying berry.
2. Yellow and dark fruit-flies—if white maggot feeds on seeds and makes dark spot at point of entry, and fruit decays and falls.
3. Fruit-worm—if a greenish caterpillar ¾ inch long feeds in berry, causing it to decay and fall.

CURRANT AND GOOSEBERRY PESTS

Currants and gooseberries are generally sprayed for only three pests: the leaf-spot, the various worms or caterpillars, and aphis. Bordeaux mixture, lead arsenate, and, when necessary, nicotine sulfate, are the only materials required, unless an outbreak of San José scale makes a dormant treatment necessary. A normal spray schedule, including the dormant spray for scale, comprises five applications.

However, there are seven important insects and diseases that currant and gooseberry growers should recognize. They are leaf-spot, anthracnose, powdery-mildew, imported and green currant-worms, imported currant-borer, currant aphis, and white-pine blister-rust (European rust, currant felt-rust).

Anthracnose

Currant anthracnose is the most common cause of leaf-spotting and leaf-blighting on currants and gooseberries. It is distinguished from leaf-spot by having much smaller spots. It also injures petioles, young canes, fruit-stalks, and fruit. Upper surfaces of older leaves become dotted with small, brown, circular spots, causing them to turn yellow and fall. The spots on berries resemble fly-specks, while on fruit-stalks and young canes small cankers extending half-way around

the stem are formed. The injury interferes with the maturing of the present crop and the ripening of wood and buds for the succeeding crop.

Anthracnose is controlled by spraying or dusting with sulfur mixtures or bordeaux mixture every ten to twenty days from the time the leaves unfold until five or six sprays have been applied. In dry weather, spraying may be less frequent.

Leaf-spot

Small brown spots about 1/8 inch in diameter cause severe leaf injury and sometimes almost complete defoliation which interferes with the maturing of the present crop and the ripening of the new wood. Bushes become devitalized. The spots appear a few weeks after growth starts in the spring. Small black fruiting bodies appear in the center of the spots.

The same spray schedule used for anthracnose will control leaf-spots.

Powdery-mildew

A whitish moldy growth in May and June on leaves, fruit, and young canes of the gooseberry may be due to powdery-mildew. Spots merge to form large patches. The leaves and stems become distorted; berries are dwarfed and sometimes crack and decay. Old spots become rusty brown.

Control may be effected by spraying with lime-sulfur, 1 to 40, or liver of sulfur, 1 ounce to 2 or 3 gallons of water, starting when the buds break open and at 10-day intervals thereafter for six or eight weeks. Wet weather or more susceptible varieties may make further spraying essential.

Green currant-worm, imported currant-worm (Fig. 133)

The larvæ of both of these insects are green and attack the foliage of the currant and gooseberry in the early spring, while later broods appear through the summer. They feed in colonies and will soon defoliate an entire plant. They may be controlled easily by applying powdered lead arsenate at the rate of 1½ pounds in 50 gallons of water as soon as they appear.

When the fruit is ripe, hellebore at the rate of 1 to 2 ounces in 2 gallons of water will control them.

Imported currant-borer

The appearance of sickly canes when foliage pushes out in the spring is frequently due to the presence of a borer. These canes should be cut out and burned before June 1 to prevent the emergence of a moth from the pupa which is contained in the cane.

FIG. 133.—Imported currant-worm damaging a currant leaf.

Currant aphis (Fig. 134)

These aphis appear on the under sides of the leaves a short time after they open, becoming abundant very rapidly, curling the leaves and causing them to fall. A honeydew which is secreted by the aphis forms a medium for the growth of a black mold which spoils the appearance of the fruit.

Control can be secured by spraying with ½ pint of 40 per cent nicotine sulfate and 2 pounds of fish-oil soap to 50 gallons of water, shooting the spray upward from beneath the leaf, using high pressures. This must be done before the leaves curl.

White-pine blister-rust (European rust, currant felt-rust)

Rust pustules appear on the lower sides of leaves from June until fall, causing the leaves to drop if infection is severe, weakening the plant, and interfering with the ripening of the fruit. But the chief cause for alarm at this disease is that it goes from the currant and gooseberry to the five-leaved white pine, killing those trees in a short time. It is controlled by

eradicating white pines within five hundred feet of a berry patch and by destroying persistently diseased plants.

Other currant and gooseberry pests

The greenish caterpillars of the gooseberry fruit-worm and the small white maggots of the yellow and dark fruit-fly often burrow in the fruit, particularly in the northern states, caus-

FIG. 134.—Aphis injury to currant leaf and shoot.

ing the berries to ripen and fall prematurely. Running poultry in the berry patch and hand-picking and destroying infested fruit will check them.

Currant stem-girdler lays eggs in the canes and slashes the tip above the egg, causing it to wilt and die. Injured

canes should be cut off 4 to 6 inches below the girdle and burned.

The gooseberry span-worm—whitish with yellowish stripes—may eat the foliage in the early spring, but lead arsenate as for currant-worms, applied when the insects appear, will control them.

Cane-blight causes the sudden wilting and dying of canes of the black currant and European gooseberry during the growing season. No method of control is known other than the removal of blighted canes as soon as they are observed.

San José scale, oyster-shell scale.. (See Apple, page 272)
Green fruit-worm, cutworms...... (See Apple, page 280)
Fruit lecanium .... (See Peach, page 314)

CHAPTER XXI

STRAWBERRY PESTS

KEY FOR DIAGNOSING STRAWBERRY TROUBLES

Foliage spotted

1. Leaf-spot—if spots are small, deep purple or red, first appearing on upper surfaces of leaves and later developing a grayish center.
2. Powdery-mildew—if leaves curl at margins and powdery or mealy patches appear on leaves and fruit, the latter drying up.

Foliage dying

1. Leaf-spot; powdery-mildew (see *Foliage Spotted*).
2. Crown-moth—if a dirty, white, brown-headed caterpillar ¾ inch long is found in the crown.
3. Root-louse—if lice are present on the leaves and buds early in the spring and summer and are later found in roots, and plants appear unthrifty. Trouble is worst on sandy soils.
4. Root-weevil—if small whitish grub ¼ inch long is eating away the roots around the crown.
5. Crown-borer—if small whitish grub 1/5 inch long, with yellow head, is working in crown.
6. White-grub—if large coarse grub 1 inch in length is around crown.

Foliage or blossoms eaten or destroyed

1. Weevil—if blossom stalks are cut off and fall just before time to bloom.
2. Leaf-roller—if yellowish to greenish-brown caterpillar feeds on leaves and rolls up in a folded leaf.
3. Flea-beetle—if a green-coppery, or blue, active beetle feeds voraciously on foliage in spring. Root-worm beetles also do this damage.
4. Thrips—if a tiny, brownish-yellow, sucking insect about 1/20 inch long appears as buds open and rasps and sucks juices from flower-buds, causing blossoms to dry up or fruit to be misshapen.
5. Slug—yellowish to greenish larvæ eat small round holes in leaves, working mostly at night.
6. Tarnished plant-bug—feeding punctures are made in young fruits, causing them to harden or become lopsided and deformed.

Fruit eaten

1. Ground-beetle—the surface of ripening berries is frequently chewed and the berries rendered worthless by the larvæ of these beetles. They feed only at night.

IMPORTANT STRAWBERRY PESTS

In spite of an imposing array of pests which trouble the strawberry, very little is done in the way of spraying by most commercial growers. A few growers will give one or two applications of bordeaux mixture for leaf-spot and to repel flea-beetles, while a larger number will dust the patch with lead arsenate and lime to control the strawberry weevil. Doubtless some regular spraying would be profitable, especially when two or three crops are to be taken off the beds.

Fig. 135.—Strawberry leaf-spot. The white centers of the dark spots distinguish it from scorch.

Leaf-spot (*sun-scald, leaf-blight*) (Fig. 135)

Purplish or red spots, becoming whitish at the centers, develop on the leaves and finally fall out, leaving holes. Badly infested leaves shrivel and die, sometimes defoliating the plant, impairing the vigor, preventing the maturity of the crop, and sometimes killing the plant.

A 4-4-50 bordeaux spray, applied before the blossoms open and twice after harvest, will control ordinary infections. The

Fig. 136.—Strawberry leaf-roller.

use of resistant varieties and the planting of disease-free stock on well-drained land are advised.

Flea-beetle

This small, steely-green, coppery, or blue flea-beetle feeds voraciously on strawberry foliage in early spring, doing great damage at times. A 4-4-50 bordeaux mixture will drive it

away. Powdered lead arsenate, $1\frac{1}{2}$ pounds to 50 gallons, will kill some of them. All evening primroses and related plants on which the flea-beetles deposit their eggs should be destroyed.

Weevil

This insect lays an egg in the flower-cluster and then girdles the stalk, causing the cluster to fall. Losses reach tremendous proportions where the insect is very prevalent. Perfect control can be secured by dusting the vines with an 80-20 mixture of sulfur and lead arsenate as they come into bloom. About 75 to 80 pounds to the acre will be required. An 85-15 mixture of hydrated lime-lead arsenate has also been quite satisfactory. As the insect prefers staminate varieties, the use of imperfect strains for the main crop and of perfect varieties every fifth row for pollination will lessen the damage done by the weevil.

Other strawberry pests

.Tiny yellowish-brown thrips do serious damage to blossoms in some districts by rasping the tender parts, causing them to wilt and die. Nicotine sulfate, $\frac{1}{2}$ pint to 50 gallons of soapy water, should be used when the insects appear.

Crown-moth, crown-girdler, crown-miner, crown-borer, Fullers' rose-beetle, black vine-weevil, root-lice, and the grubs of several other beetles feed on the roots and crowns, causing them to wilt. Infested plants should be dug and burned. Only clean plants should be planted. Abandoned beds should be plowed up.

Leaf-rollers (Fig. 136), slugs, rose-chafers, and the beetles of several root-worms feed on the foliage. Dusting vines with an 85-15 mixture of hydrated lime and lead arsenate will control them. Tarnished plant-bugs, negro-bugs, and white-fly sometimes suck juices from the plants. They are difficult of control.

Powdery-mildew, making a whitish mealy growth on the under sides of the leaves, is serious in some localities. A 4-4-50 bordeaux mixture will control it, if applied when the disease appears. Botrytis rot sometimes produces hard brown spots

FIG. 137.—Strawberry leaf-scorch. These spots have no white centers.

on the berries, which must be sorted out in packing. Spraying is ineffective. Leaf-scorch (Fig. 137) sometimes spots the leaves somewhat similar to leaf-spot, but is controlled incidentally with leaf-spot, by spraying with 4-4-50 bordeaux mixture.

CHAPTER XXII

IMPORTANT CRANBERRY PESTS

Black-headed cranberry-worm (fire-worm) (Fig. 138)

This green caterpillar webs together leaves at the tips of the cranberry upright and feeds on them in the spring, the tips turning brown. A second brood webs together several tips and feeds on the tips, buds, fruit, and foliage, the vines looking scorched—hence the name fire-worm. It is controlled by spraying with 3 pounds of powdered lead arsenate to 50 gallons when the caterpillars hatch, and by flooding the beds for three days when the first-brood pupæ are on the ground, not allowing the water to cover the vines.

Yellow-headed cranberry-worm

This caterpillar does damage similar to that of the black-headed worm, but is controlled by holding the winter water on the bogs in the early spring until the moths have disappeared or by spraying dry bogs with lead arsenate as above.

Span-worm, false army-worm

These pale green span-worm caterpillars and yellowish measuring army-worms eat foliage and buds in the early spring. The control measures for fire-worms, as above, will check them.

Cranberry-worm (Fig. 139)

This pale green larva enters the calyx-end of the berry and eats pulp, thus often destroying several berries which drop prematurely. Flooding bogs for ten to fourteen days after

harvest will control the insect in low bogs. In dry bogs, spraying the fruit with 1 pound of paris green and 2 pounds of

Fig. 138.

Fig. 139.

Fig. 138.—Black-head worm on cranberries. Webbing of shoots by second brood of larvæ.

Fig. 139. — Cranberry-worm injury to berries. The large berry is uninjured.

resin-fish-oil soap in 50 gallons of water, at the time the larvæ are entering, is recommended.

Cranberry-girdler (Fig. 140)

This grayish caterpillar feeds on the bark of prostrate

stems of the vine, killing them. Sometimes spots of considerable size appear scorched as if by fire. Flooding the vines

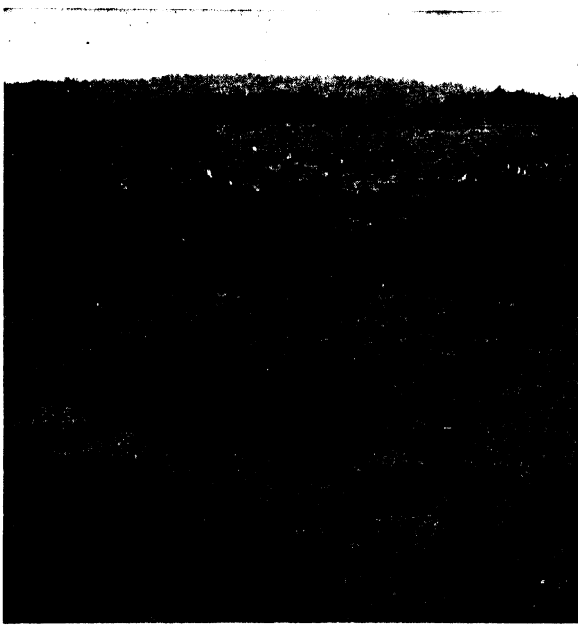


FIG. 140.—Cranberry-girdler injury. Vines in the foreground have been killed by this insect.

seven to ten days immediately after harvest will control them. On dry bogs the badly infested spots are burned with a gasoline torch.

Scald, rot (Fig. 141)

These two diseases look so similar that it is easy to confuse them. Watery surfaces on the berry enlarge and soften, look-

ing as if scalded, sometimes shriveling. Flowers occasionally are blistered, while leaves sometimes become dotted with brown spots, turn yellow, and fall. A 5-5-50 bordeaux mixture, plus 2 pounds of resin-fish-oil soap as a sticker, should be applied five times at intervals of two weeks, starting two weeks before blossoming (Fig. 142). Water supply should be kept as even as possible.

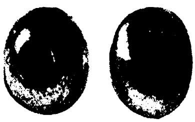


FIG. 141.—Cranberry scald.

FIG. 142.—Spraying cranberries with bordeaux mixture. The hose is run onto the bogs upon rollers on top of stakes, and men carry the free end by means of straps over the shoulders.

Gall

Reddish galls are found on stems and leaves and occasionally on flowers and fruit. Badly infested beds are rendered worthless. Burning of beds in early winter is advised.

Other cranberry insects and diseases

Gall-fly, katydid, fulgorid, hypertrophy, anthracnose, cotton-rot (Fig. 143).

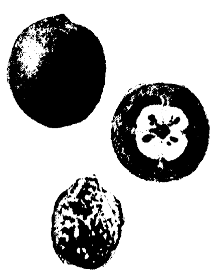


FIG. 143.—Cranberry cotton-rot.

CHAPTER XXIII

CITRUS PESTS

KEY FOR DIAGNOSING CITRUS FRUIT TROUBLES [1]

Foliage mottled

1. Mottle-leaf—if light colored areas appear between veins and areas which have normal dark green color, giving a mottled appearance.
2. Exanthema—if small mottled leaves follow the appearance of coarse very dark green leaves, and young growth dies back.

Foliage spotted

1. Citrus-canker—if foliage, fruit, and twigs have round raised spots, covered with a grayish or a whitish membrane.
2. Scab—if spots are circular or irregular, with large light to dark brown scabby masses; leaves warped and misshapen in severe cases.
3. Melanose—if spotted with small, round, hard, shiny, slightly elevated spots.
4. White-fly—if the spots are small whitish soft-bodied insects.
5. Scale of various species—if the spots are insects covered with hard shells.

[1] The following publications were consulted for the material on citrus fruits:

Fawcett, H. S., and Lee, H. A., *Citrus Diseases and Their Control.* McGraw-Hill Book Co. 1926.

Stevens, H. E., *Florida Citrus Diseases,* Fla. Agr. Exp. Sta. Bull. 150. 1918.

Watson, J. R., *Insects of a Citrus Grove,* Fla. Agr. Exp. Sta. Bull. 148. 1918.

Quayle, H. J., and Knight, Hugh, *The Control of Citrus Insects,* Calif. Agr. Exp. Sta. Circ. 129. 1923.

Woglum, R. S., *Fumigation of Citrus Trees for Control of Insect Pests,* U. S. Dept. Agr. Farmers' Bull. 1321. 1923.

Yothers, W. W., *Spraying for the Control of Insects and Mites Attacking Citrus Trees in Florida,* U. S. Dept. Agr. Farmers' Bull. 933. 1918.

Foliage abnormally green

1. Exanthema or die-back—if leaves are coarse and large, followed later by development of small mottled leaves; and accompanied by a dying back of young growth and formation of gum pockets on twigs.

Foliage dropping

1. Scab—if spotted with large light to dark brown elevated scabby masses, with wart-like projections and crinkled distorted leaves.
2. Wither-tip—if twigs start dying at the tip, and disease works back down the twig, and fruit is tear-stained.
3. Purple-scale, red-scale, and other sucking insects which weaken the trees.
4. Blast (citro-necrosis)—if brown or black area develops around a break in leaf, changing later to reddish-brown scabby lesions. Dropping is worse in warm weather.

Foliage crinkled and distorted

1. Scab—if spotted with large light to dark brown, circular or irregular elevated scabby masses, with wart-like projections and, in severe cases, the dropping of leaves.
2. Thrip injury, aphis injury—if small soft-bodied sucking insects are present, or have been present within the crinkled and rolled leaves.

Foliage dying

1. Exanthema—if accompanied by very dark green, or mottled foliage, and formation of gum pockets at nodes.
2. Twig-blight—if leaves wither and hang on twigs and drops of gum form at points of infection on twigs.
3. Wither-tip—if leaves die at tip, disease works back down the twigs, leaves are shed, and fruit is tear-stained.
4. Blast (citro-necrosis)—if brown or black areas develop around breaks in leaves, which die on trees if disease develops rapidly.
5. White-fly or scale insects, if very prevalent.

Fruit small

1. Mottle-leaf—if foliage has light green patches between the darker green veins.
2. White-fly—if trees are infested with the insect, and honeydew coats the tree.
3. Rust-mite—if accompanied by loss of the glossy appearance of the leaves, and a rusty "buckskin" appearance of fruit.

Fruit spotted

1. Melanose—if spots are small, circular, hard, brown, shiny, and slightly raised, sometimes running together to form masses, or areas.

2. Scab—if spots are large, light to dark brown, circular or irregular, elevated, with wart-like projections, and the leaves are crinkled and distorted.

3. Canker—if spots are round, raised, and covered with a whitish or grayish membrane, and the leaves and twigs are similarly spotted.

4. Wither-tip or anthracnose—if the spots are brown and extend from an inch in diameter to half the area of the fruit, or if small red spots develop four or five weeks after picking, especially while the fruit is in transit.

5. Black-pit—light brown sunken spots develop usually around injuries, turning darker, finally becoming black. Usually about ¼ to ½ inch in diameter, and worst on lemons.

6. Peteca—sunken, whitish or slightly discolored dry spots develop on lemons in storage, due to collapse of cells under surface of rind. If soaked, rind will regain normal condition.

7. Exanthema—brownish, glossy, gum-soaked areas in superficial layers, later becoming glassy hard layers on surface; and gum may form in angles of segments at core.

8. Nail-head rust—if spots are at first sunken brown rings, developing into sunken brown spots.

9. Thrips—if spots are smooth brownish sunken areas, often encircling the fruit. Sunken area has thinner skin.

10. Rust-mite—if spots have rusty or "buckskin" appearance, and extend over most of the surface.

Fruit dropping

1. Brown-rot—if fruit has dark brown leathery pliable rot with characteristic odor.

2. Exanthema—if portions of the foliage have abnormally green or mottled color and new shoots are dying.

3. Melanose—if small hard, circular, brown, shiny, slightly raised spots are present, appearing shortly after fruit is set.

4. Wither-tip—if twigs die at tip, disease runs back down the branch, and many leaves are shed, and fruit is tear-stained.

Fruit stained or discolored

1. Exanthema—if stains are brownish-red and elevated and frequently cracked longitudinally.

2. Wither-tip—if leaves at tips of twigs die, and dead area extends down twig, and fruit develops brownish-red streaks, extending regularly from the stem to the blossom-end.

3. Rust-mite—if the fruit has a rusty or "buckskin" appearance, accompanied by loss of glossy appearance of foliage.

4. Sooty-mold—if white-fly, various scale insects, or other honeydew-secreting insects are present to deposit the honeydew on which the black mold grows.

Fruit rotting

1. Brown-rot—if a light brown rot, developing in wet weather, and having a characteristic odor.

2. Cottony-mold—if, especially on lemons, decayed areas become covered with a white mycelium.

3. Blue-mold, green-mold, gray-mold—if decayed areas become covered with a powdery substance of these colors.

4. Anthracnose and wither-tip—if spots are brown and extend from ½ inch in diameter to half the area of the fruit, tips of twigs die back, and fruit is tear-stained.

5. Sour-rot—very soft sour watery buff-colored rot causing the tissues of fruit to disintegrate, with liquid escaping.

6. Alternaria-rot—if rot is a brownish or black interior rot, spreading along the core or inner rind, fruit finally breaking down.

Twigs and branches dying

1. Exanthema—if accompanied by abnormally dark green foliage, or mottled foliage, formation of gum pockets at nodes, and formation of reddish gum in cracked branches.

2. Mottle-leaf—if foliage has light colored areas between darker green veins, particularly near the ends of the shoots.

3. Twig-blight—if the leaves wither and hang on twigs, drops of gum form at points of infection, and small black fruiting-bodies form on bark near infection point.

4. Blast—if infection from leaf-petiole extends into the twig, girdling and killing it. Dead area is reddish-brown.

5. Wither-tip—if dying starts at tip and works down the branch, and fruit is spotted and tear-stained. On limes mature twigs and leaves, and fruit larger than ¾ inch in diameter are quite immune to attack.

Twigs and branches cankered and gummy

1. Exanthema—if accompanied by abnormally dark green foliage, a dying back of new shoots, and a formation of reddish gum in cracked branches.

2. Twig-blight—if leaves wither and hang on twigs, and drops of gum and black fruiting bodies develop at points of infection.

3. Blast—if reddish-brown lesion develops at base of petiole of leaf, or canker runs down young twig.

4. Canker—if spotted with round elevated cankers covered with grayish or whitish membrane; and if the fruit and twigs are similarly spotted.

Trunk cankered and gummy

1. Brown-rot gummosis—if gum exudes from just above bud union, especially on lemon trees, but frequently on oranges and grapefruit; surrounding bark being dead and raised from the wood slightly.

2. Foot-rot or mal-de-gomma—if bark dies and decays at or below the surface of the ground, with an oozing of gum.

3. Psorosis (California scaly-bark)—dead scales of bark ¼ inch to 1 inch in diameter, with live bark underneath, or with small pimples or pustules under which are brown specks. Later gum is found under the bark, and on the surface. Usually found on bark older than six years.

4. Shell-bark of lemon—cracking or shelling of long vertical strips of bark on trunk or larger limbs of lemon, with new bark building up underneath. Sometimes accompanied by gumming.

Roots dying

1. Armillaria root-rot—brownish cord-like growths just under bark, and wet rot of the wood.

2. Dry root-rot—moist decay starts on larger roots at some distance from surface, with slight gumming, later turning to hard brown dry decay.

3. Mal-de-gomma and brown-rot gummosis—bark dying and decaying just below the surface of ground, with copious gumming, usually spreading upward rapidly to the crown.

METHODS OF CONTROLLING CITRUS PESTS

Citrus fruits are troubled by an exceptionally large number of pests of the first magnitude. The scale insects are numerous in variety, most generally prevalent, and hardest to keep under control. In addition to these a large number of fungous troubles, particularly in Florida, make the problem of crop protection one of greatest importance.

Spraying is the generally accepted method of control practiced in Florida. A few combination insecticidal and fungicidal sprays are applied that will keep most of the pests entirely in subjection. Fumigation with hydrocyanic-acid gas has not

been as satisfactory in Florida as in California, because of the damper atmospheric conditions and the shorter dormant season.

In California fumigation is regularly practiced for the control of scale insects, although in the past few years there has been a tendency to turn to spraying, particularly since the advent of the lubricating oil emulsions. Quayle and Knight [1] believe that spraying will not be as satisfactory for California as fumigation, due to the necessity of spraying more frequently, susceptibility of the citrus trees to spray-injury, and the relative impossibility of thorough control especially of the black scale, because of the dense head of the tree, which makes thorough penetration and coverage difficult. Spraying is a satisfactory means of control in Florida, however, perhaps because the black scale is not as serious there.

Spraying

Spraying practices for citrus trees do not differ from those in deciduous orchards, except perhaps in the greater difficulty in getting thorough coverage in the interior portions of the trees. According to Yothers [2] the spray-gun has not been satisfactory in controlling scale insects and white-fly because of the trouble in coating the under sides of branches and leaves in the interior of the dense low-headed trees. The use of the bamboo spray-rod, with two nozzles with 1/16 inch apertures in the discs has been more suitable to Florida conditions.

Grapefruit and oranges are the principal citrus fruits grown in Florida. Usually a spray schedule consisting of five applications is sufficient to insure perfect fruit in average seasons, and in orchards where spraying is done regularly and thor-

[1] Quayle, H. J., and Knight, Hugh, Calif. Agr. Exp. Sta. Circ. 129, 1923.

[2] Yothers, W. W., U. S. Dept. Agr. Farmers' Bull. 933. 1922.

oughly. Additional applications are required in certain seasons, or where the pests are particularly prevalent. The spray schedule for Florida groves is shown on pages 400 and 401.

Fumigation

In California[1] fumigation consists of covering the trees with canvas tents, and liberating certain charges of hydrocyanic-acid gas or calcium cyanid dust beneath these tents. Hydrocyanic acid is the most widely used. Calcium cyanid is a newer material, being first employed by Quayle in the summer of 1922. His experiments were successful and since that time there has been a considerable interest in the new dust.

Few individuals have holdings of sufficient size to warrant the maintenance of the extensive equipment necessary for efficient fumigation. Therefore, the work is done largely by companies who contract for the job at a stipulated price. Some of the local packing house associations maintain fumigating service, the work being done at cost. Another method is coöperative fumigation, where a group of growers form a fumigating association, the work being accomplished coöperatively under a manager elected by the growers.

Equipment required

Considerable equipment is required. Tents, ropes and poles for raising them, containers for chemicals, and generating apparatus comprise the principal items. Flat cloth tents of octagonal shape are made in standard sizes based on distances between parallel sides. The sizes commonly used are 36, 41, 43, 45, 48, 50, 52, 55, 64, 72, and 81 feet. The size will depend on the size of the trees to be fumigated and will range as follows:

[1] Following material compiled from Calif. Agr. Exp. Sta. Circ. 129, 1923, and U. S. Dept. Agr. Farmers' Bull. 1321, 1923.

Tent Sizes	*Tree Heights*
36-41 foot tents	up to 10 feet
41-43 and 45 foot tents	11 to 15 feet
45-48 and 52 foot tents	16 to 20 feet
55-64 and 72 foot tents	21 to 25 feet
81 and 84 foot tents	25 feet and over

The most satisfactory material thus far found is United States Standard Army duck, either 7 or 8 ounce. For very large tents sometimes a light tightly woven canvas called

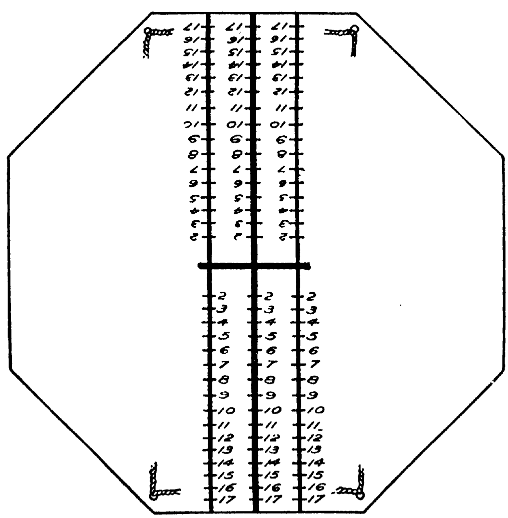


FIG. 144.—Fumigation tent marked according to the Morrill method.

United States shelter duck is used on the sides,—only the large center strip, which takes the most wear and tear, being of the 8-ounce canvas. The number used by one crew ranges from fifteen to ninety, about thirty being an average. The

commonest sizes are 41 to 48 feet. Under favorable conditions one tent will cover from twelve to fourteen trees a night, but the average for the fumigating season is about five to seven, making a seasonal total of 375 to 450 trees to a tent each year.

Tents must be shrunk, mildew-proofed, and marked. Shrinking is done by laying them flat and soaking them with water. Mildew-proofing, usually practiced only in Florida, is accomplished by dipping them in a vat containing either a hot solution of 40 pounds of extract of oak bark in 100 gallons of water, or a solution containing 5 pounds of sal soda, 10 ounces of tartaric acid, 5 pounds of zinc sulfate, in 200 gallons of water.

Special markings are required on the tent to facilitate the computation of charges of gas to be given the trees inclosed. The Morrill marking system is shown in Fig. 144. Often the parallel lines are omitted, and the rows of numbers are done in distinctive sizes or shapes so that the tape man can distinguish a particular column on opposite sides of the tented tree.

Poles are used in lifting all but very large tents. These are from 2 to 2½ inches in diameter, and 14 to 20 feet long. They are made from straight grained hard pine. A half-inch rope is secured about 6 inches from one end of the pole, and is long enough to reach 2 or 3 feet beyond the opposite end. The tent is secured to the pole by placing a fold of the cloth over the end of the pole and catching it with a half hitch of the rope. Sometimes the canvas is furnished with metal grommets, in which case metal pegs in the ends of the poles are slipped through them.

Derricks are used on very tall trees. A rope and pulleys facilitate raising the tent. The rope should be about three times the height of the derrick. Derricks are cumbersome and much disliked and their use is avoided whenever possible.

As the pot system of fumigating with sodium or potassium cyanid has been almost entirely superseded by the use of

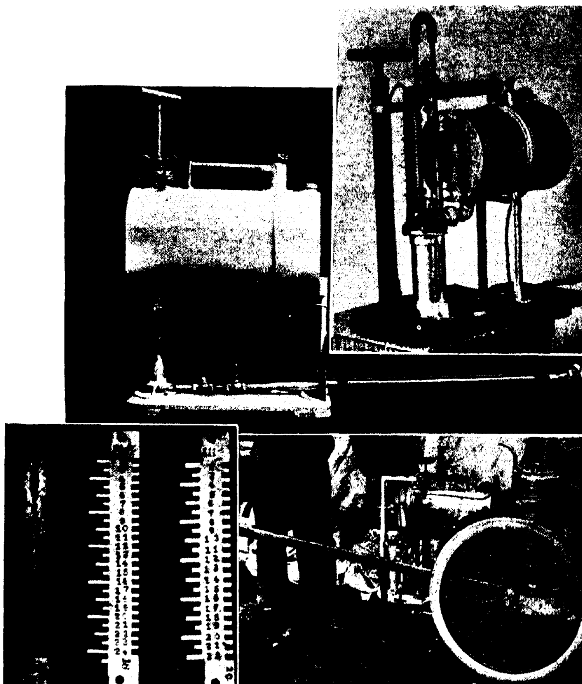


FIG. 145.—Top, left, machine for applying liquid hydrocyanic acid beneath tented trees by movement of the plunger; right, a liquid-gas machine for delivering hydrocyanic acid; the liquid is forced out of the measuring chamber by air pressure. Bottom, left, interchangeable gauges which deliver 88, 100 and 111 per cent dosages; right, machine for vaporizing liquid hydrocyanic acid; the measured liquid is passed through coils of pipe jacketed in hot water, heat for which is supplied by a gasoline burner; vaporization is immediate.

either liquid hydrocyanic acid or calcium cyanid, it will not be discussed here. With liquid hydrocyanic acid, a special atomizer is required. It consists of a tank holding 2½ gallons of hydrocyanic acid, a graduate for measuring the dosage, and a pump and spray-nozzles for atomizing the acid. (See Fig. 145). These applicators should be tested daily to establish the accuracy of the delivery. Water may be used for this purpose and can be caught in a can as it comes from the nozzles and, measured in a cubic centimeter graduate. The accuracy can also be checked by weighing the machine at the beginning and end of each row.

When calcium cyanid is employed, the material in finely divided dust form is blown into the tent by means of a small duster (Fig. 146). Dusters which measure the exact dosage are in use now in Australia. Similar ones are being introduced in the United States. In case the duster does not measure dosages automatically, each charge must be measured separately and put in the machine.

The material is a deadly poison, and requires special handling. It boils at 80° F. Pressure develops at such warm temperatures, necessitating care in opening drums, to avoid the sudden expulsion of the contents. Cool storage rooms are essential and many concerns have special storage buildings cooled by water sprinkling systems or even by ice. The drums of acid should be taken to the field as late in the day as possible before needed and placed in the shade and covered with wet sacks, or otherwise protected.

Factors influencing fumigation

Temperature. Fumigation at too high or too low temperatures is likely to injure the tree. Fifty degrees is a safe minimum when hydrocyanic acid is used. The maximum varies with districts, 75° F. being observed in the coastal regions, while 80° F. is the limit for the interior.

Wind. Fumigation should not be practiced when there is

sufficient wind to sway the tents, as some of the charge is lost when the skirts of the tent flap, and also because of the more rapid escape of the gas through the canvas. Injury to trees follows fumigation when the air is charged with electricity, as is occasionally the case when dry winds blow off the desert

FIG. 146.—Top, hand dust-applicator for calcium cyanid fumigation; bottom, the first power dust-applicator.

in California. These winds are usually accompanied by high temperatures and low humidity.

Light. Plants fumigated in direct sunshine or exposed to bright sunshine immediately after fumigation are frequently seriously injured, depending on the strength of gas used. Fumigation is carried on at night in summer, but toward winter, as the weather cools, work is commenced before sunset. During the dormant season in winter, daytime fumigation may be practiced in cloudy weather, or even started early on cool afternoons, provided dosages are not heavy. Lemons are more resistant to injury than oranges. Daylight fumigation is safer when humidity is high than when it is low.

Moisture and humidity. Fumigation should cease when there is sufficient moisture in the air to wet the tents, as damp tents become gas-tight and the gas concentration may become too high for the trees. Wet tents are difficult to handle, and collect dirt, and are likely to injure fruit when being pulled over the tree. Gas burning follows slight abrasions on the skin of the fruit.

Soil conditions. Trees in wet spots have been noted to be more susceptible to gas injury. Fumigation is safest when the soil is dry. It follows that irrigation should not precede fumigation. Cover-crops, irrigation furrows, prunings, clods, or other factors which might prevent the tents from resting closely on the ground deter efficient fumigation. The orchard should be harrowed smooth.

Spraying. Injury has followed fumigation of trees sprayed with bordeaux mixture, possibly due to interaction between the copper in the bordeaux and the hydrocyanic acid. The injury is characterized by leaf-drop, defoliation sometimes occurring. This type of injury has been noted by Woglum as long as six months, and in a few cases eleven months after spraying. When spraying the lower branches of the trees and ground with bordeaux mixture in the autumn to prevent brown-rot is practiced, the spraying should follow fumigation

by several days. Trees sprayed with oil or sulfur solution can be fumigated afterward without danger of injury due to reaction with spray material.

Dosages

A "dosage" is the amount of cyanid gas required to kill any certain insect. The unit employed in California is the amount of gas generated by an ounce of cyanid. However, hydrocyanic gas is developed from several sources, so special dosage tables are required for each source.

Insects differ in amounts required for their destruction. This introduces another variable factor in arranging fumigation schedules. Therefore a standard, or 100 per cent schedule has been adopted for each material, and then different insects are treated with certain proportions of this standard schedule varying from 77 to 122 per cent strengths. To facilitate the calculations, tables have been prepared for different strengths, while the applicators which spray the liquid hydrocyanic acid have interchangeable gauges which regulate the pump action so that exactly the right amount of acid is sprayed into the tent to give the proper percentage of a standard dosage. These gauges are shown in Fig. 145.

Quayle[1] recommends 20 cubic centimeters of liquid hydrocyanic acid as the equivalent of 1 ounce of sodium cyanid, while Woglum [2] recommends 18 cubic centimeters. Fig. 148 shows the 100 per cent dosage schedule calculated for 95 to 98 per cent pure liquid hydrocyanic acid.

Special tapes can be secured with 100 per cent dosage already marked on them, thus doing away with the necessity of referring while in the orchard to tables each time a tree is measured. (See Fig. 147.) These tapes, together with the interchangeable dosage gauges on the applicators, have reduced

[1] Quayle, H. J., and Knight, Hugh, Calif. Agr. Exp. Sta., Circ. 129, 1923.

[2] Woglum, R. S., U. S. Dept. Agr. Farmers' Bull. 1321. 1923.

to a minimum the chances of error in dosing a tree, as no calculations have to be made in the grove.

The tent is pulled over the tree and centered as accurately as possible, which brings one of the three parallel tapelines approximately over the center of the tree (see Fig. 149). The one most nearly over the center is read. The distance over the top is obtained by adding the two numbers that occur where the line over the top of the tree touches the ground on opposite sides. The distance around the tree at a heighth of about three feet above the ground is measured by the operator with a tapeline with a catch arrangement on one end, with which it may be hooked to the tent. All measurements should be taken accurately. The distances around and over the tree are traced in the schedule tables, and the proper dosage is thus secured.

For example, if the tree is 36 feet over by 42 feet around, examination of the schedule shown on page 384 indicates that 14 units, or 14 x 18 cubic centimeters, totalling 252 cubic centimeters of liquid hydrocyanic acid are required to give a 100 per cent dosage to the tree. If the Quayle and Knight schedule is used (in which 1 ounce of sodium cyanid is calculated to be equivalent to 20 cubic centimeters of liquid hydrocyanic acid), the dosage would be 14 x 20 cubic centimeters, totalling 280 cubic centimeters to give the 100 per cent dosage to the tree.

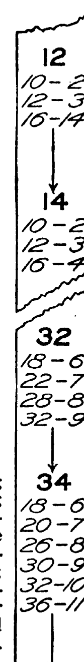


Fig. 147.—Showing method of marking the dosage on a fumigation tape. Large numbers represent distance around in feet; left-hand column represents distance over the tree; right-hand column, the dosage. (Liquid-gas schedule.)

The tents are spread out on the outside of the end row of trees, one tent at the side of each tree. The seams of the tent are always placed in the direction the tent is to be pulled.

(DISTANCE AROUND IN FEET)

DISTANCE OVER (IN FEET)	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48		50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	
10	2	2	3	3	3															10																10
12	3	3	3	4	4	4	4													12																12
14	3	3	4	4	4	4	5	5												14																14
16	4	4	4	4	5	5	5	5	5	5										16																16
18	4	4	4	5	5	5	5	5	6	6	6	6	6							18																18
					20	22	24	26	28	30	32	34	36	38	40	42	44	46	48		50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	
20					5	5	6	6	6	6	6	7	7	7	7	7				20																20
22					5	6	6	6	6	7	7	7	7	7	7	7	8	8		22																22
24					6	6	6	6	7	7	7	7	8	8	8	8	9	9		24																24
26								7	7	7	7	8	8	9	9	9	10	10	10	26	11															26
28									7	7	8	8	9	9	10	10	11	11	11	28	12															28
										30	32	34	36	38	40	42	44	46	48		50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	
30										8	8	9	10	10	11	11	12	12	12	30	13	13	14	14	14											30
32											9	10	10	11	12	12	13	13	14	32	14	15	15	15	16	16										32
34												10	11	12	13	13	14	14	15	34	15	16	17	17	17	18	18	18								34
36												11	12	13	14	14	15	15	16	36	17	17	18	18	19	19	20	20	21							36
38													13	14	14	15	16	17	17	38	18	18	19	20	20	21	21	22	22							38
															40	42	44	46	48		50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	
40																16	17	18	18	40	19	20	21	21	22	22	23	24	24	25	25					40
42																	18	19	20	42	21	21	22	23	23	24	25	25	26	26	27	28				42
44																		20	21	44	22	23	23	24	25	26	27	27	28	28	29	30	30			44
46																				46	23	24	25	26	27	27	28	29	29	30	31	32	32	33		46
48																				48	24	25	26	27	28	29	30	31	31	32	33	34	34	35	36	48
																					50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	
50																				50	25	26	27	28	30	30	31	32	33	34	35	36	36	37	38	50
52																				52				30	31	32	33	34	35	36	37	38	38	39	40	52
54																				54					32	33	35	36	37	38	39	40	40	41	42	54
56																				56						35	36	38	39	40	41	42	42	43	44	56
58																				58						36	38	39	40	41	42	43	44	45	47	58

FIG. 148.—Dosage schedule for citrus fumigation with liquid hydrocyanic acid, 95 to 98 per cent pure.

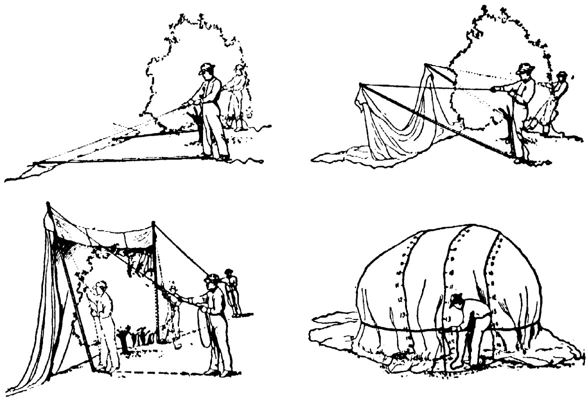


FIG. 149.—Successive stages in placing a tent over a tree with poles.

The poles are put in position and secured to the tent either through rings provided, or by catching a double fold of the canvas over the end of the pole and securing it with a half hitch as shown in Fig. 150. The tent is then raised as shown in Fig. 149. Care should be taken not to pull the tent too far over the tree. Centering the tent will come with a little practice. The poles are then detached and the skirts of the tent are kicked in so they hang perpendicularly from the sides, and at the same time examined to see that they lie close to the ground at all points, and the pullers proceed to the next tree. The generator then applies the acid.

FIG. 150.—Method of attaching tent to hoisting pole by means of half-hitch.

Trees should be exposed to the hydrocyanic gas for approximately one hour. Therefore, the number of tents operated

by a gang of four or six men will be limited to such as can be moved from row to row within an hour's time. Tents ranging from 36 to 43 feet are commonly handled by two pullers. Tents above 45 feet are usually handled by four pullers. Crews of six men can usually manage from 45 to 70 tents in an hour depending on conditions. Each crew has, in addition to the pullers, a generator who applies the dosages and a foreman who supervises the work and keeps a record of the operation.

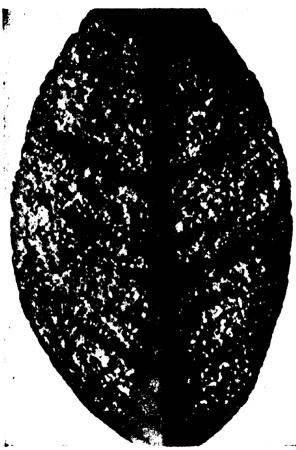


FIG. 151.—Woolly white-fly on citrus leaf.

Charts showing the orchard, date, time, temperature, humidity, condition of tents (whether dry or damp), wind, sunshine, tree, row, dosage, dosage schedule, insect, system of fumigation, size of tents, direction tents are moved, and amount of material used, should be kept by the foreman.

IMPORTANT CITRUS FRUIT PESTS

White-fly (Fig. 151)

Several species of yellow- or orange-colored insects, covered with whitish scale which give them the appearance indicated by the name, are responsible for the greatest insect losses to Florida citrus-growers. According to Watson,[1] the larvæ suck the juices out of the tree and secrete a honeydew which covers the tree and upon which a black fungus called

[1] Watson, J. R., Fla. Agr. Exp. Sta. Bull. 148. 1918.

sooty-mold (Fig. 152) develops, making the tree and fruit unsightly, and necessitating a washing of the fruit. The mold itself interferes with production of starches by the tree, due to the cutting-off of the light from the leaf surfaces. The greatest damage is done through the loss of sap, which weakens the tree, checking the growth and greatly reducing the crop.

FIG. 152.—Sooty-mold on fruit and leaf.

These insects are controlled by spraying with oil emulsions or miscible oils in late April or in May, waiting until after the young fruits are an inch in diameter so that they will not be injured by the spray; by the introduction and spread of the red and yellow Aschersonia, the brown fungus, and other parasitic fungi, spores of which are suspended in water and sprayed on the trees in June and July; and by a second application of oil emulsion made in August or September, about two weeks after the adults have largely disappeared.

Purple-scale

This purplish-brown scale, shaped somewhat like an oyster-shell and about ⅛ inch long, sucks the juices out of the leaves, fruit, trunk, and branches, checking the growth of the infested part and in severe cases causing the leaves to fall, while the fruit on such trees remains small and is slow to color. Scale

punctures also form entry holes for some of the destructive fungi.

Control in Florida is effected by spraying as for white-fly, using scale-infesting fungi in addition. In certain moist localities and seasons purple-scale is fairly well controlled by red-headed, white-headed and black fungus without spraying. If the infestation is very severe, it may be necessary to put on a supplementary spray four weeks after the summer application, or six weeks after the winter one. Fumigation with hydrocyanic gas is practiced in California, where the 100 per cent schedule of 20 cc units is used.

The citricola scale (Fig. 153)

The citricola scale is a more recent pest in California. According to Quayle and Knight [1] it appears mostly in May, June, and July, and the injury is due both to the feeding of the insects and to the honeydew and sooty-mold, which necessitates washing the fruit. Fumigation should take place before the first of September, using a 100 per cent dosage wherever possible. Later in the season a 111 per cent dosage may be necessary.

Florida red-scale (*California red-scale, yellow-scale*) (Fig. 153)

The Florida red-scale according to Watson,[2] is dark reddish-brown, almost circular in outline, and about 1/12 inch in diameter when full grown. It is more pernicious than the purple-scale, almost defoliating trees upon which it becomes abundant, but it is not as generally distributed as the purple-scale. It is controlled in the same way as the purple-scale, except that, having a thicker shell, it usually takes the supplementary oil spray beside the two regular sprays to kill it. When spraying with the spores of parasitic fungi, the spores of the pink fungus should be added for Florida red-scale. In

[1] Quayle, H. J., and Knight, Hugh, Calif. Agr. Exp. Sta. Circ. 129. 1923.

[2] Watson, J. R., Fla. Agr. Exp. Sta. Bull. 148. 1918.

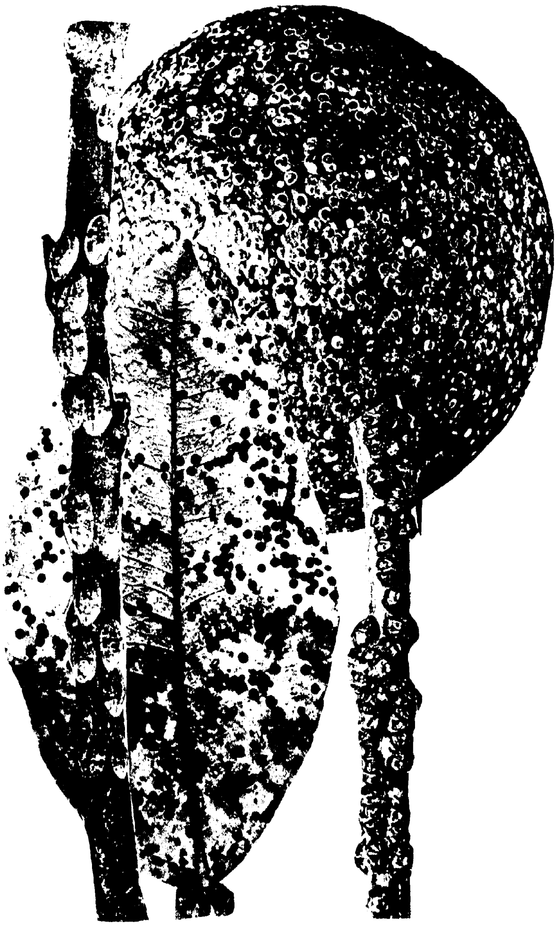


FIG. 153.—Left, citricola scale on twig; Florida red-scale on leaf, showing adult females and young scales. Right, California red-scale on orange; black-scale on citrus twigs.

California it is best controlled by fumigation with hydrocyanic gas. A 100 per cent schedule should be used, except when the scales are unusually resistant, when a 111 or even a 122 per cent dosage may be required. Fumigation may be done at any season.

Black-scale (Fig. 153)

The black-scale is the most troublesome in California. It infests the twigs primarily, although it gets on both leaves and fruit. It sucks out the juices and secretes a honeydew on which the sooty-mold develops, making a thorough washing of the fruit necessary before packing. This scale may be plainly identified by the prominent letter H on its back. It is not important in Florida. It is controlled by fumigating with hydrocyanic gas, spraying with oil emulsion, and by several fungus and insect parasites. In fumigating, a 100 per cent schedule, with a 20 cc unit, should be used wherever practicable. In coastal districts where there is danger of injury to fruit with this dosage a 77 or 88 per cent schedule may be substituted. Fumigation should start shortly after September first.

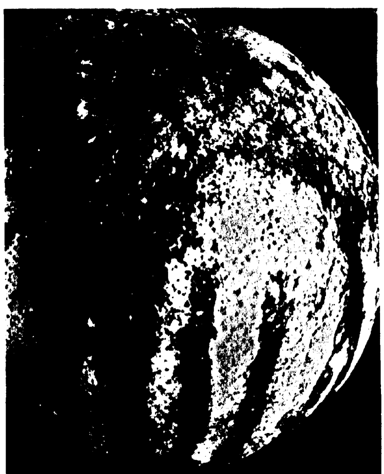


FIG. 154.—Rust-mite tear-stain on grapefruit.

Rust-mite (Fig. 154)

According to Watson this tiny insect, 1/200 of an inch long, sucks out the oils and juices from the leaves and fruit, interfering with their development, detracting from their appearance by making a rusty or "buckskin" marking on the surface, reducing the size, and delaying the coloring so that the

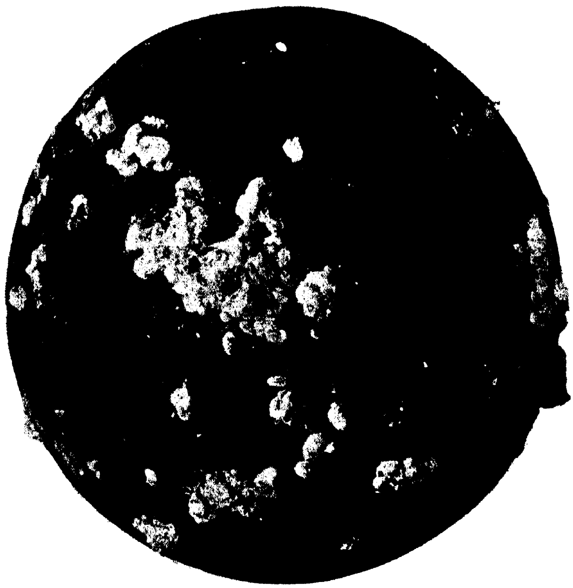


Fig. 155.—Mealy-bug infesting grapefruit.

fruit cannot be marketed early. Leaves lose their glossy appearance and look dry, and are really injured as much or more than the fruit. The mites multiply most rapidly in dry weather. Frequent examination of fruit and foliage with a hand-lens is necessary to detect the insect. Lime-sulfur, 1 to 75, sulfur-lime dust, 35 to 65, or superfine sulfur, at the rate of 1 to 5 pounds to 50 gallons of water to which 3 or 4

pounds of fish-oil soap have been added, will control the mites. Soluble sulfur added to the oil emulsions will make them more effective against the rust-mites.

Other citrus insects

Red-spider	Thrips
Mealy-bug (Fig. 155)	Cottony cushion-scale
Orange-dog	Snow-scale
Plant-bugs	Chaff-scale

Brown-rot (Fig. 156)

This fungus attacks both the trunk of the tree and the fruit. On the fruit it causes rotting both on the tree, where it is worst on low branches within three or four feet of the ground, and in the packing-house. Severe losses may occur on the tree in especially wet seasons. The decay is watery and brownish, with a peculiar and characteristic odor. On the trunks the gum exudes copiously from just above the bud union, particularly on lemon trees, but frequently on oranges and grapefruit as well. The surrounding bark dies, and becomes hard and dry, often raised from the cambium by gum formation.

Fig. 156.—Brown-rot on lemon.

To control brown-rot the soil should be pulled away from the trunk down as far as the top of the first main roots, water kept from the trunks, bordeaux paste applied to the trunks on very heavy soils, as a preventative, and one should

avoid striking the trunks with tools. Budding six inches high on good sour-orange or other resistant stocks will reduce losses. All diseased tissue should be cut away and painted with bordeaux paste made of 1 pound of bluestone and 2 pounds of stone lime. The fruit in the packing-house may be protected by adding bluestone to the washwater at the rate of 1½ pounds to 1,000 gallons. H. S. Fawcett[1] advises heating the washwater to 120° F. and immersing the fruit for two to three minutes.

This disease in Florida is controlled by cultivating well under the trees and pruning the branches up off of the ground. In California the ground and lower branches of the trees are sprayed with 3-3-50 bordeaux mixture in October and November, preceding the rainy season.

Exanthema, or die-back

The leaves on parts of the tree may develop abnormally dark green coarse foliage, followed by a dying back of young growth, and formation of gum pockets at the nodes, which often burst and exude the gum. Larger twigs crack and exude reddish-brown gummy material. The fruit on badly affected branches falls, or remains small, or exhibits slightly elevated brownish-red stained areas which often crack longitudinally. The fruit is thick-skinned, has gum pockets at center, and insipid flavor. Direct causes for exanthema are not known. In Florida it is usually associated with too heavy applications of organic nitrogen, hardpan, and lack of drainage, while in California its appearance is correlated with poor drainage and other unfavorable soil conditions. Correction of the causes removes the trouble.

Mottle-leaf, chlorosis, foliocellosis

These terms are applied to various conditions associated

[1] Fawcett, H. S., and Lee, H. A., *Citrus Diseases and Their Control.* McGraw-Hill, 1926.

apparently with soil deficiencies, resulting in partial or complete yellowing or mottling of the leaves. The causes are not definitely known, but it is thought that inability of the leaves to obtain sufficient iron, magnesium, calcium, or potassium is

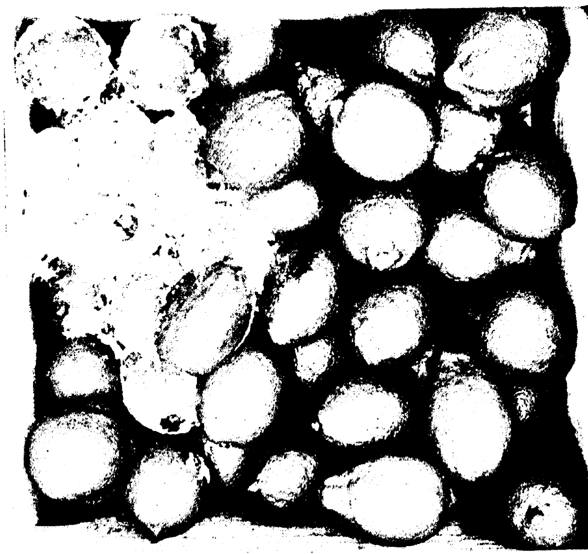


FIG. 157.—Cottony-mold spreading through a box of lemons.

the main cause. The veins remain a dark green. As the trouble increases yields decrease, and the fruit remains small and pale in color. Many branches die back and sickly shoots put out from large limbs. The use of bulky cover-crops is advised. Lipman, of the California Experiment Station, suggests injecting iron sulfate into the citrus trees for chlorosis.

Twig-blight, cottony-rot

Three fungi cause twig-blight but only one is serious, the Diplodia blight. *Sclerotinia libertiana,* which blights twigs, does more damage to fruit in packing-houses than to trees in the orchard. The withering of leaves on the twigs and branches up to an inch in diameter, the dead leaves hanging to the twigs, is an evidence of twig-blight. Drops of gum form

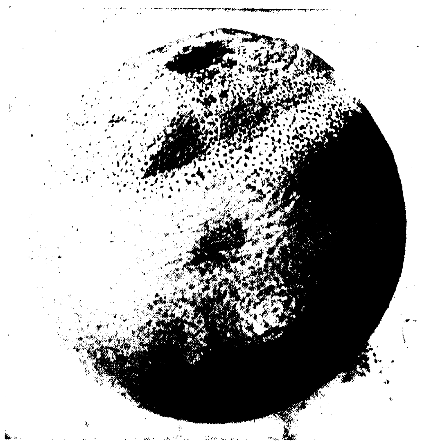


FIG. 158.—Mold on orange.

at the point of infection and small fruiting-bodies develop on the outside of the bark near the point of infection. In the packing-houses the cottony-rot develops especially on lemons, which decay and are covered with a cottony mycelium, which spreads rapidly to the sound fruit (Fig. 157).

The trouble is believed to be due to lack of vigor, to faulty soil conditions, or seasonal deficiencies. In the orchard maintaining a vigorous tree growth is desirable. Blighted twigs should be cut out. In the packing-house the picking boxes

should be disinfected with strong bluestone solution, not allowing them to stand on cover-crop or dead organic matter, which may also harbor the disease. Cover-crops should not be planted for a few years in orchards in which cottony-mold is serious.

Blue-mold, green-mold, gray-mold (Fig. 158)

These molds develop rapidly on fruits which have been injured by handling or other means, causing a blue, green, or gray powder to appear over the diseased area, hence the names. Careful handling of the fruit to avoid any injury to the surface is the best remedy. Barger and Hawkins have found that treatment of the fruit in the packing-house for five minutes in a 2.5 per cent solution of boric acid or borax at a temperature of about 125° F. will reduce losses from these molds. One company has patented a successful treatment consisting of washing the fruit in borax solution and coating the surface with a slight covering of hot paraffin. Hundreds of cars of fruit were shipped without ice during the summer of 1926 under this treatment, which is called the Brogdex and Brogdite treatment.

Citrus-canker (Figs. 159, 160)

This disease, first appearing in 1912, threatened to become one of the most serious on citrus. It attacks all varieties except the kumquat, producing a round raised spotting of fruit, foliage and twigs, the spots occurring singly, or running together to cover a large area, especially on the fruit. The diseased portion is covered with a thin white or grayish membrane. Citrus-canker does not kill the twigs, but forms spots through which other fungi can gain entrance. It is spread by wind, or anything coming in contact with the damp cankered surfaces and then touching other citrus tissue. Complete destruction of all canker-infested trees is the only effective method of control known.

Anthracnose or wither-tip

Light green spots appear near margins or tips of mature leaves, soon turning brown, and pinkish spores ooze from tiny dark pustules in damp weather. Twigs die back, the withered leaves frequently hanging, similar to die-back. The disease usually attacks weak trees first. On the fruit hard depressed brown spots develop on the rind, the infection occasionally entering the flesh of mature fruits to cause a soft brown rot. Another symptom on the fruit is "tear-stain," a rusty area extending from the top of the fruit toward the blossom-end, resembling the path of a drop of water.

Maintenance of the vigor of the trees is a good preventative, while thorough pruning or even drastic cutting of very seriously injured trees is essential, particularly in Florida. Cuts should be

FIG. 159.—Citrus-canker on leaf.

smooth and close, and large wounds should be painted. Fawcett suggests spraying with lime-sulfur or bordeaux mixture to prevent tear-stain where the disease is serious. In dry regions, as in California, spraying is not often necessary. In Florida the pruning and spraying schedule for scab and melanose usually takes care of anthracnose.

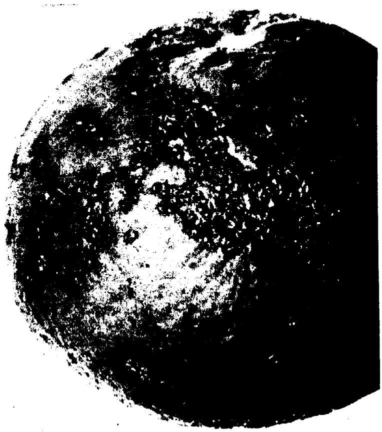


FIG. 160.—Citrus-canker on summer orange.

Melanose

Melanose, caused by the fungus *Phomopsis citri*, is responsible in Florida and many other citrus districts except California, for much of the unsightly fruit. It is evidenced by the appearance of small circular hard brown, shiny, slightly raised spots, caused by gum-filled cells. The spots often run together to form irregular masses, blotches or streaks, sometimes affecting the entire surface. These spots are superficial and cause no rotting of the fruit, but injure the sale value. Frequently the fungus causes severe dropping of newly set fruits and foliage from young twigs, the latter often dying. Old leaves and fruit are immune. Control is effected in Florida by thorough spraying with 3-3-50 bordeaux mixture plus 1 per cent of lubricating oil, ten to twenty days after two-thirds of the bloom has dropped. In case of serious infection it may be well to apply another

spray of the same materials a month later. Pruning out dead wood is another beneficial treatment.

Scab

The scab fungus attacks sour oranges, lemons, grapefruit, and Satsumas particularly, making circular or irregular elevated wart-like masses or projections on the surface of leaves, fruit, and twigs. The color varies with the host somewhat, ranging from green to yellow, orange, or brown, and even dark red on old injury. It is particularly prevalent in the Gulf states. Generally only young tissues are attacked, and weather conditions greatly influence the severity of the outbreaks, it being necessary to have moist weather at time of spore discharge and development of young growth on which the spores may alight. Dry weather at the time spores are being discharged accounts for the failure of the fungus to do damage in California. Infected leaves become crinkled and distorted, and, if severely infected, the shoots shed their leaves and die. Fruits become warty and misshapen, and considerable shedding of fruit may occur if the disease gets a foothold at the time the fruit is setting. The interior of the fruit is not affected, but it makes a low-grade unsightly product. One type of injury due to the disease is the blossom-blight, causing the shedding of many blossoms.

When serious, four sprays are recommended: (1) Just before growth sets in, use 3-3-50 bordeaux mixture, plus 1 per cent oil emulsion; (2) at height of bloom, with 3-3-50 bordeaux plus ½ per cent oil emulsion; (3) two weeks later, with same material as in 2; (4) two weeks after the third application, using the same materials as in the first spray.

If scab is only moderate in its effect, 1 to 40 lime-sulfur may be substituted for the bordeaux mixture in sprays 2 and 3, while if it is of only slight importance lime-sulfur may be used in all of the sprays, 1 to 30 in the first, and 1 to

A SPRAY SCHEDULE FOR CITRUS

No.	FRUIT	ENEMY	MATERIALS	TIME OF APPLICATION	REMARKS
1	Grapefruit	Scab	Bordeaux oil mixture (3-3-50)	JUST BEFORE THE FIRST FLUSH OF GROWTH	Bordeaux mixture plus 1% of oil in the form of an oil emulsion stock solution. (See remarks under No. 7.)
2	Grapefruit	Scab rust-mites red-spiders	Lime-sulfur solution (32° Baume); 2 ½ gals. in 100 gals. water	JUST BEFORE THE PETALS OPEN	To be applied, if scab infections appear on the new growth, or, if rainy weather favorable for scab follows No. 1.
3	**Grapefruit and oranges**	**Scab, thrips rust-mites red-spiders**	**Lime-sulfur solution, 2 ½ gals., and 13 ozs. nicotine sulfate to 100 gals. of the spray solution**	**WHEN 1/3 TO 1/2 THE PETALS ARE OFF**	**Add the nicotine, if 25 or more thrips to the bloom are present. If thrips are abundant but no scab, use 1 ½ gallons lime-sulfur and 2 pounds nicotine-sulfate solution to 100 gallons.**
4	**Grapefruit**	**Scab**	**Lime-sulfur solution, 2 ½ gals. in 100 gals. water**	**7 TO 10 DAYS AFTER 1/3 TO 1/2 THE PETALS ARE OFF**	**Lime-sulfur will also kill rust-mite and red-spiders, and for thrips 12 ounces nicotine-sulfate are added. Bordeaux oil is not as effective as lime-sulfur for above insects.**
		Scab and melanose	**Bordeaux oil**		
5	Grapefruit and oranges	Scab, scale-crawlers rust-mite	Lime-sulfur solution, 2 ½ gals. in 100 gals. water	14 TO 20 DAYS AFTER 1/3 TO 1/2 THE PETALS ARE OFF	To be given if rainy weather favorable for scab or melanose follows No. 4.
		Scab & melanose	Bordeaux oil		
6	Grapefruit and oranges	Rust-mites tear-stain	Lime-sulfur solution, 1 ½ to 2 gals. in 100 gals. water	APRIL 5th TO 15th	If any two lime-sulfur sprays out of Nos. 3, 4, and 5 have been given, this can be omitted; otherwise, this is the critical spraying for rust-mite on grapefruit.

7	**Grapefruit and oranges**	**White-fly scale insects rust-mites**	**Oil emulsion, 1% plus 2½ lbs. dry soda-sulfur in 100 gals. water**	**IN MAY WHEN THE FRUIT IS AT LEAST 1 INCH IN DIAMETER**	**The oil emulsion should be used so that the diluted spray material will contain 1% oil; that is, if the emulsion contains 66% oil, 1½ gallons would be required for 100 gallons water.**
8	**Grapefruit and oranges**	**Rust-mites tear-stain**	**Lime-sulfur solution, 1½ to 2 gals. in 100 gals. water**	**IN JUNE**	**On oranges this is the critical rust-mite spray, if the fruit has not received any previous lime-sulfur applications.**
9	**Grapefruit and oranges**	**White-fly scale insects**	**Oil emulsion 1%**	**PREFERABLY IN SEPT. OR OCT., BUT CERTAINLY BEFORE FEB. 1st**	**To be given, if scale insects or white-fly are noticeable.**
10	Grapefruit and oranges	Rust-mites	Lime-sulfur solution, 1½ to 2 gals. in 100 gals. water	NOVEMBER TO JANUARY	To be given only if rust-mites are noticeable.

The following spray schedule represents the combined judgment of W. W. Yothers, entomologist, and J. R. Winston, pathologist, U. S. Department of Agriculture; O. F. Burger, pathologist, H. E. Stevens, former pathologist, and J. R. Watson, entomologist, Florida Experiment Station; and E. W. Berger, entomologist, Florida State Plant Board. It is issued as Bulletin 30, of the Extension Division of the University of Florida.

This combined schedule is based on the work to date of state and federal investigators and represents their composite judgment regarding the control of certain citrus insects and diseases by spraying. **The five applications in heavy type (Nos. 3, 4, 7, 8 and 9) are recommended as sufficient for the control of the enemies usually destructive on grapefruit in an average season, provided the spraying is done thoroughly. Oranges will ordinarily require only four applications (Nos. 4, 7, 8 and 9).** Under conditions especially favorable for disease or insect increase some of the remaining applications may be required also.

The scab applications indicated for grapefruit also may be required on highly susceptible varieties of oranges, especially of the kid-glove type.

Application No. 3 will be required on oranges only when thrips are abundant.

Be cautious about using lime-sulfur solution when the temperature is above 90° F. If applied under this condition, use the weaker strength and be sure of the accuracy of the Baume test and of the diluting.

Bordeaux mixture requires 3 pounds bluestone and 3 pounds lime in 50 gallons water. Get the best grade of fresh stone lime obtainable. **Never use air-slaked lime.** If hydrated lime or an inferior grade of quick lime must be used, make it 4 pounds.

40 in the second and third, and the fourth spray may be omitted.

Mal-de-gomma or foot-rot

This fungus results in a dying and rotting of the bark, at or near the surface of the ground, on trunk or roots. The bark decays and the gum oozes out slightly, and the disease may soon spread to girdle the tree. Infection usually takes place beneath the surface and has progressed considerably before it is noted. The use of sour stocks for budding, the avoidance of low moist locations, and prompt cutting out and disinfection of diseased areas is recommended. In warm weather treated roots may be left exposed for a few weeks.

Nailhead rust (leprosis, scaly-bark)

Sweet oranges in damp locations in Florida are attacked by this disease, which causes brown sunken spots or rings on the fruit, and round or oval, raised, reddish spots 1/16 to ½ inch across on wood six to nine months old or older. These spots on the wood break longitudinally into small flakes or scales. The spots eventually may coalesce to girdle and kill the branch or twig. In California another disease called scaly-bark, or psorosis, somewhat resembles nailhead rust in its later stages, but is not confined to sweet oranges.

Spraying with 3-3-50 bordeaux mixture, as for scab, and pruning out diseased wood as far as possible are recommended. If very serious, top-working to resistant varieties of citrus, such as grapefruit or mandarin, or heading back diseased trees in late winter, leaving only the trunks and stubs of large branches, and painting the entire bark and cut surfaces with an emulsion made of 1 gallon of carbolineum, 1 gallon of water, and 1 pound of whale-oil soap, followed by spraying to protect the new growth, will control the disease.

Other citrus diseases

Shell-bark	Stem-end-rot	Black-rot
Citrus-knot	Armillaria root-rot	Diplodia rot
Sooty-mold		

CHAPTER XXIV

PESTS OF ASPARAGUS, ONION AND CHIVE

IMPORTANT ASPARAGUS PESTS

Only two pests of any magnitude attack asparagus. These are the rust, and the asparagus-beetle. Fortunately both are easily controlled, the former by using resistant varieties, and the latter by spraying, dusting and some other common practices.

Rust (Fig. 161)

This disease attacks the tops of the asparagus plant which develop after cutting for market ceases. Elongated reddish pimples arise on stems and needles, causing the tops to turn yellow and the stalks to die, weakening the crowns which are already depleted by cutting for market, and thus reducing the crop for the following year. Weak plants and those growing in locations visited by heavy dews are most subject to the disease.

Control is secured by the use of resistant varieties, planting on moist rich soils to keep the plants growing vigorously, irrigation (if possible) in dry weather, planting in locations having good air drainage, and by spraying with 5-5-50 bordeaux mixture to which has been added a resin sticker, or by dusting with sulfur. Three applications are usually sufficient.

Asparagus-beetle and twelve-spotted asparagus-beetle

A black and gold beetle eats holes in asparagus tips, while the larvæ, appearing a few days later, also feed on the tips,

and later both larvæ and adults feed on stems and leaves, seriously checking the plant. The running of poultry in the bed is the easiest method of control, fifteen to twenty chickens to an acre keeping the insects well in check. Cutting the crop clean every three to five days, the use of an occasional trap

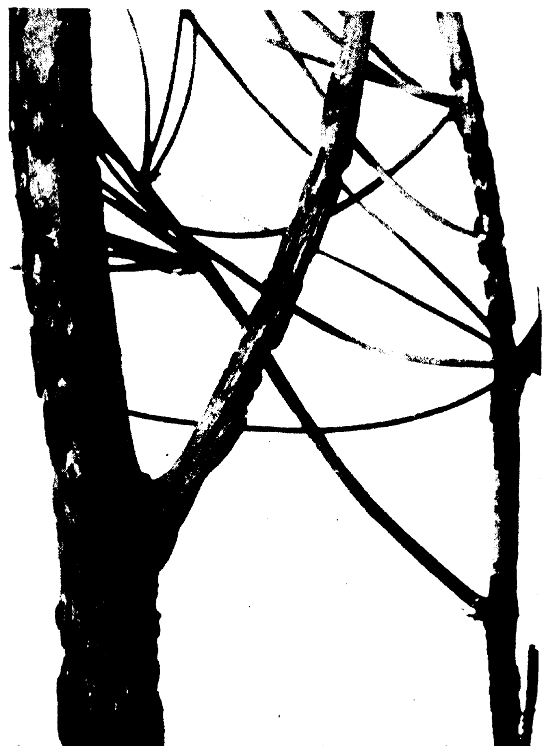


FIG. 161.—Rust on asparagus.

row which is sprayed every few days with $1\frac{1}{2}$ pounds of powdered lead arsenate to 50 gallons of water, and the spraying of infested fields three times after the cutting season is over as above, will control the insect. Dusting with an 85-15 mixture of hydrated lime and lead arsenate is also practiced, four or five rows being covered at one time with a power-duster. Hand-dusters will keep the insect down in the home garden.

KEY FOR DIAGNOSING TROUBLES OF ONION AND CHIVE

Foliage yellow

White-rot, downy-mildew.

Foliage spotted

Neck-rot, downy-mildew, onion-smut.

Foliage eaten

Onion-thrips.

Stems injured or dying

Onion-maggot.

Roots or bulbs injured or dying

Soft-rot, onion-maggot, wire-worm, seed-corn maggot, pink-root, white-rot.

Fulbs spotted

Anthracnose, onion-smut, smudge, neck-rot.

IMPORTANT ONION AND CHIVE PESTS

Spraying, use of resistant varieties, soil sterilization, seed treatment, crop rotation, and sanitary measures are all used in combating enemies to plants in the onion family. Spraying is directed particularly at the onion-maggot, where five applications at regular intervals are made. The material is applied by gravity feed so the operation cannot truly be called spraying.

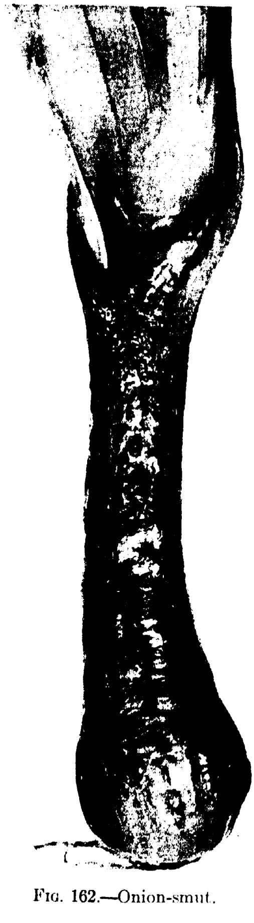


Fig. 162.—Onion-smut.

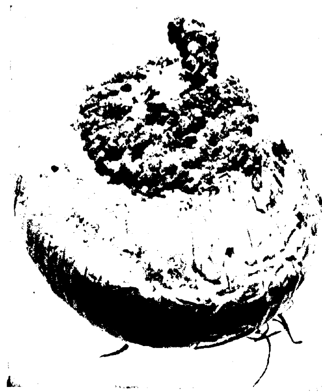


Fig. 163.—Neck-rot of onion.

Onion-maggot

A small white maggot bores into the bulb, injuring or killing the onion. The bulb decays as it dies. Five applications of bordeaux oil emulsion, made of 4-4-50 bordeaux mixture and a potash fish-oil soap and lubricating-oil emulsion of 2 per cent concentration, applied with a drip attachment to the young onions every week, starting when the plants are an inch high, will control this pest.

Onion-thrips

These insects rasp the onion leaves and suck up the juices,

whitish blotches showing where the injury has been done. Tops die, and finally the onions. The best methods of control are spraying with 40 per cent nicotine sulfate at the rate of 1 pint to 50 gallons of water and 4 pounds of soap, dusting with 1½ per cent nicotine dust, cleaning up crop remnants in fields after harvest, and practicing clean cultivation.

Other onion family insects

Cutworms	Wire-worms
Seed-corn maggot	Blister-beetle

Downy-mildew

Purple spots can be seen on the affected leaves on a dewy morning. The leaves turn yellow and the tops of the plants collapse. New tips are sent out, but loss of the tops reduces the size of the onion. Planting in fertile well-drained soils and occasional spraying with 5-5-50 bordeaux mixture, the number and time of applications depending on the amount of wet weather, will usually control this disease. From two to four sprays are generally sufficient.

FIG. 164.—Onion smudge or anthracnose.

Onion-smut (Fig. 162)

Dark streaks within the tissue of the leaves and bulbs are due to smut. These streaks crack, exposing the spores. Infected seedlings usually die. The use of onion sets, the sowing of seeds in clean seed-beds

and transplanting to the field, and the disinfection of the soil with 500 to 700 gallons to the acre of formaldehyde solution made up of 1 pint of formaldehyde to 30 gallons of water applied with a drip attachment are the best means of control.

Neck-rot (Fig. 163), *pink-rot, white-rot, smudge*

These diseases are frequently very serious in most onion sections, but they cannot be controlled by spraying. Pink-rot, smudge and white-rot occur in the field. The first is recognized by the pinkish color of the roots which later die. White-rot is characterized by a rotting at the base of the bulb, a white moldy appearance developing. Neck-rot appears as sunken dried-out places on the bulbs, or elongated yellow areas on the foliage. It appears principally in storage.

Crop rotation, seed treatment, careful handling, drying and storage conditions, are recommended to hold the losses by these troubles to a minimum.

Anthracnose (or smudge)

Black spots on the onion bulbs, appearing usually in storage, are caused by anthracnose (Fig. 164). Proper curing of the crop and the use of a well-ventilated dry storage, in which low temperatures can be maintained, will usually prevent the disease from becoming serious.

Other onion family diseases

Black-mold
Bulb-rot
Pink-rot
Soft-rot
Neck-rot
Rust
Botrytis rot

CHAPTER XXV

PESTS OF THE BEAN AND PEA

KEY FOR DIAGNOSING BEAN AND PEA TROUBLES

Foliage yellow

Bean thrips, pea and bean aphis, bacterial bean-blight, powdery-mildew, wilt.

Foliage spotted or mottled

Anthracnose, powdery- and downy-mildew, leaf-blotch, Septoria leaf-spot, mosaic, rust, pod-spot, red-spider.

Foliage eaten

Bean, leaf-beetle, weevils (bean-, pea-, broad-bean-, and cowpea-), Mexican bean-beetle, green clover worm, caterpillars, army-worm, cutworm, leaf-roller, spotted cucumber-beetle.

Foliage wilting or dying

Bean thrips, aphis, lima-bean vine-borer, anthracnose, bacterial bean-blight, wilt, powdery-mildew, Sclerotinia rot, Rhizoctonia rot (Fig. 165).

Beans spotted

Bacterial bean-blight (if spots are yellow); anthracnose (if spots are black); pod-blight, pod-spot.

Pods spotted

Downy-mildew, pod-blight, pod-spot, rust, Rhizoctonia rot.

Pods eaten

Corn ear-worm.

Roots eaten

Grubs of bean leaf-beetle, wire-worms, nematodes (eel-worm).

Roots dying

Wilt, pea root-rot.

IMPORTANT PEA AND BEAN FAMILY PESTS

Pea and bean aphis, Mexican bean-beetle, and bean-mildew are the principal troubles for which sprays are used. Sprays or dusts are applied only when the pests appear, to keep them from spreading. Mildew is usually worse in wet weather than in dry, and more spraying must therefore be done to hold it in check. Several foliage-eating insects may be troublesome at times, but these are controlled by sprays applied after the pests appear. No regular spray schedule is recommended. With arsenical sprays it is advisable to use either calcium or magnesium arsenate, as lead arsenate frequently injures the plants, particularly in the South and East.

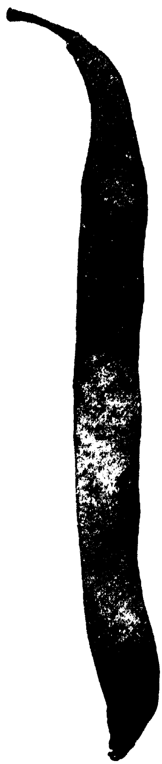


FIG. 165.—Rhizoctonia rot on bean.

Mexican bean-beetle (Fig. 166)

A yellow or brownish ladybird beetle with sixteen black marks and its spiny yellow larvæ feed on the lower surfaces of bean leaves, when severe, killing the plant. Infestation occurs in the South and East. Markovitch[1] recommends dusting the vines with 1 part of sodium fluosilicate to 9 parts of hydrated lime (by volume) to control this insect. Thorough applications of calcium or magnesium arsenate spray, 1 pound to 50 gallons of water, applied to the lower sides of the leaves has been an effective control measure. Spraying has been more generally successful than dusting.

[1] Markovitch, S., Tenn. Agr. Exp. Sta. Bull. 131. 1924.

Pea-weevil, bean-weevil, broad-bean-weevil, cowpea-weevil

Weevils feed on the foliage and lay eggs on pods, the larvae feeding on the pod. Control methods are to plant clean seed and fumigate stored seed (see Chapter XXXVII).

Bean leaf-beetle (Fig. 167)

Adults of the bean leaf-beetle feed on the leaves. Their feeding marks are round regular holes distinguishing them

FIG. 166.—Mexican bean-beetle, nymphs and adults.

from the irregular holes made by the Mexican bean-beetle. Sometimes they completely defoliate the plant. The grubs feed on the roots. Calcium and magnesium arsenate sprays on the under sides of the leaves when the beetles appear will control them. Hand-picking is practiced in the home garden.

Bean thrips

A tiny thrip sucks the juices from the leaves, which turn yellow and die, frequently killing the plant. One-half pint of 40 per cent nicotine sulfate and 2 pounds of fish-oil soap to 50 gallons of water, or a 5 per cent nicotine dust will control them.

FIG. 167.—Bean leaf-beetle.

Pea aphis (Fig. 168)

A large green plant-louse sucks the juices of the leaves, blossoms, and pods. It is the most serious pea insect enemy. Plants become yellow and die. The insects are controlled by spraying or dusting as for bean thrips, as above, and by avoiding the planting of clover, especially crimson clover, near pea fields. J. E. Dudley of Wisconsin, has designed a machine

known as an "aphidozer" which collects the aphids from the pea vines (Fig. 169, 170). The machine shows promise as a means of combating aphis where peas are sown for canning, as the return from this crop does not warrant the expenditure of large sums for spraying with costly insecticides. Dudley has secured better results with the aphidozer than with nicotine dusts in some tests.

Fig. 168.—Pea aphis on shoot.

Bean aphis

A black louse does damage similar to the pea aphis, and is controlled by nicotine sprays or dusts as for bean thrips.

Green clover-worm, striped green bean-caterpillar, gray hair-streak, bean leaf-roller, and corn ear-worm

The larvæ of these moths feed on the foliage, pods, and seeds, at times doing considerable damage. Most of them may be partially controlled by calcium or magnesium arsenate sprays. No satisfactory spraying method has been devised to control the corn ear-worm.

Other bean insects

Cutworms	(See cabbage, page 427)
Army-worms	(See cabbage, page 427)
Flea-beetle	(See cabbage, page 428)
Blister-beetle	(See cabbage, page 428)
Harlequin-bug	(See cabbage, page 426)
Green soldier-bug	(See cabbage, page 426)
Lima bean borer.	

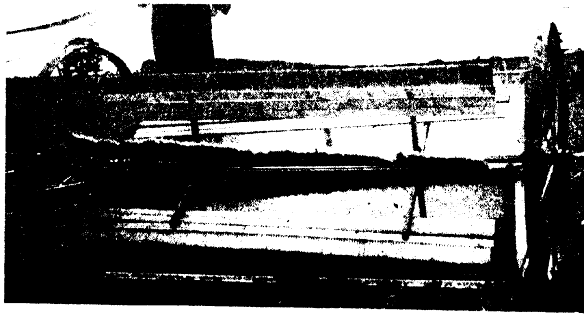


FIG. 169.—The Dudley aphidozer.

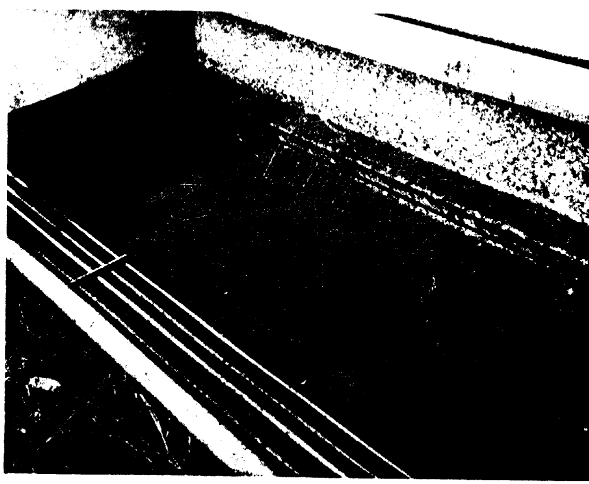


FIG. 170.—Thirty pounds of aphids in hopper of aphidozer after brushing 1½ acres. Note the absence of broken foliage in the hopper.

Powdery-mildew

White mealy patches on leaves and stems, which cause the leaves to yellow and fall, are due to powdery-mildew. Dusting with finely powdered sulfur will control it. Planting rows farther apart will lessen the disease.

FIG. 171.—Downy-mildew on lima bean.

FIG. 172.—Bean-blight on leaf.

Downy-mildew (Fig. 171)

A felt-like, dirty-white, mycelial growth is caused on pods,

causing them to shrivel and die, and a purplish discoloration is seen on the leaves. The seed is shriveled.

Control consists of discarding all shrivelled seed, rotating crops, staying out of fields while plants are wet, burning all

FIG. 173.—Bean-blight.

FIG. 174.—Anthracnose on beans and pod.

refuse after harvest, and spraying two to four times with bordeaux mixture during the growing season.

Pod-blight, leaf-blotch, leaf-spot

These fungi cause large brown patches on leaves, pods, and seeds, greatly reducing yields. Bordeaux sprays for downy-mildew will control them.

Other bean and pea diseases

Several other diseases attack these crops but are not to be controlled by spraying. Bacterial bean-blight (Figs. 172, 173)

FIG. 175.—Pea root- and stem-rot.

causes a yellowing and wilting of the plants, as if they had been scalded, while the diseased seed appears shrivelled and blotched with yellow.

Anthracnose (Fig. 174) causes black sunken spots on seeds and tiny red spots on leaves, petioles and stems, causing defoliation.

FIG. 176.—Pea pod-spot.

Wilt (yellows) is characterized by yellowing plants, dead small roots and a browning of the interior of stems and main roots.

Pea root-rot (Fig. 175) destroys the roots, killing the plant when severe.

Pod-spot (Fig. 176) and Septoria leaf-spot affect the stems and pods with a grayish spot, sometimes girdling the stems. Seeds become infected from the pods.

For these diseases, and several others, the only methods of control are crop rotation, use of clean seed, resistant varieties, and cultivation only during the dry portion of the day.

CHAPTER XXVI

PESTS OF BEET AND SPINACH

KEY FOR DIAGNOSING BEET FAMILY TROUBLES

Foliage yellow

Downy-mildew, leaf-spot, acid soil.

Foliage spotted

Leaf-spot, downy-mildew, bacterial-spot, smut, spinach leaf-miner.

Foliage eaten

Beet leaf-beetle, webworm, cutworms, army-worms, cucumber-beetle.

Foliage dying

Aphis, downy-mildew, leaf-spot, bacterial-spot.

Foliage curled

Curly-leaf, aphis, leaf-hopper.

Roots eaten or spotted

Corn root-worm, root-louse, scab, crown-gall, smut.

Roots dying

Root-louse, root-rot, damping-off, soft-rot, water-core.

IMPORTANT BEET AND SPINACH PESTS

The prevailing methods of controlling beet and spinach pests are dusting or spraying for aphis, leaf-hoppers, and leaf-beetles when they appear, supplemented by stimulation of the plants to enable them to outgrow the attacks of the insects, the growing of disease-resistant varieties, such as the Virginia Savoy yellows-resistant spinach, crop rotation and seed disinfection and sanitation. No regular spraying schedule is

recommended. Such spraying as may involve the use of arsenicals should be practiced only when the plants are young, as there is some danger of having sufficient arsenical residues left to endanger human health, if plants are sprayed with arsenicals within a few weeks before harvest. The exact safety point in this regard is not known, but utmost caution should be observed so no arsenical residues are present when the spinach is harvested.

Beet leaf-beetle (larger sugar-beet, and western)

Adults and larvæ feed on the leaves, causing considerable defoliation. Spraying with 1½ pounds of powdered lead arsenate in 50 gallons of water when the beetles appear will control them.

Beet leaf-hopper

Swarms of these hoppers occasionally settle on fields, sucking out juices and frequently infecting the plants with curly-top, an obscure disease which makes the leaves leathery and sometimes stunts and kills them. Commercial control methods have not been worked out satisfactorily. Growing the crop early and taking measures to make the plants as vigorous as possible, so as to withstand the attacks of the leaf-hoppers, are recommended.

Webworms: sugar-beet, Hawaiian beet, southern beet, spotted beet

Larvæ feed on the under sides of the leaves, finally consuming them, and covering the feeding ground with a slight silken web. The injury of the first brood to young plants may be very severe. Spraying at 100 pounds pressure or more, with 1½ pounds of paris green and 3 pounds of fish-oil soap, or 2 pounds of lime as a sticker, to 50 gallons of water when the caterpillars first appear will control the larvæ. About 100 gallons to the acre should be applied.

Spinach aphis (green peach aphis)

These green aphis appear on the under sides of the spinach leaves and suck out the juices, stunting and sometimes killing the plants. They may be controlled by spraying with $1\frac{1}{2}$ pints of 40 per cent nicotine sulfate and 3 pounds of fish-oil soap to 50 gallons of water, or by dusting with $1\frac{1}{2}$ to 2 per cent nicotine dust, using a canvas trailer to hold the dust on the plants.

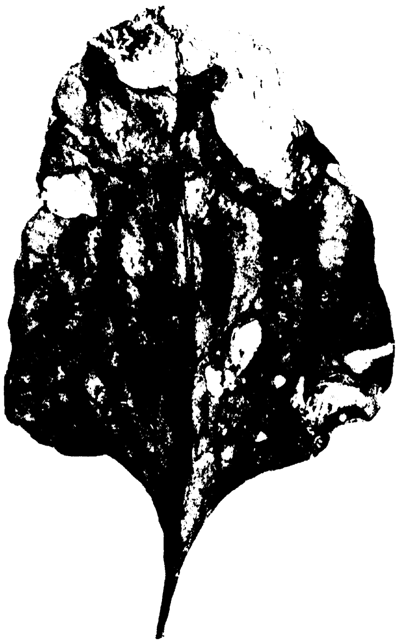


FIG. 177.—Beet leaf-miner injury.

Spinach leaf-miner (Fig. 177)

The maggot of this insect mines between the leaf surfaces of spinach, beet, mangels and chard, forming a blotch of dead tissue. These, when numerous, kill the leaf, and the maggots move to a new leaf. Spraying is ineffective, but growing the crop in early spring and late fall avoids the worst infestations.

Sugar-beet root-lice

These insects collect on the roots of sugar-beets, sucking

out juices and reducing the weight and sugar-content of the root. Spraying is not practicable, but where irrigation is practiced the plants may be forced into enough growth to withstand the attacks of the root-lice.

Other spinach and beet insects

Cutworms	(See cabbage, page 427)
Army-worms	(See cabbage, page 427)
Cucumber-beetles	(See melon, page 445)
Corn root-worm	(See corn, page 440)
Flea-beetle	(See cabbage, page 428)
Blister-beetle	(See cabbage, page 428)

Leaf-spot (Fig. 178)

Small circular white spots appear, turning brown as they develop, causing the leaf to become brittle and dry. Roots become elongated and undersized. Removal of crop remnants, deep fall plowing, crop rotation, and spraying with 4-4-50 bordeaux mixture are recommended.

Root-rot, damping-off, soft-rot, water-core

These troubles are thought to be due to faulty soil conditions, such as lack of drainage, poor soils, acidity, lack of aeration, and other factors. The use of crop rotation, drainage, and building up the soil by cover-crops and fertilizers are advised.

FIG. 178.—Beet leaf-spot.

Crown-gall (tuberculosis)

Outgrowths or tumors of various sizes appear on the roots of beets. Fields will sometimes not grow beets because of this disease. A crop rotation which does not include beets, tomato, potato, cabbage, radish, or salsify should be resorted to for several years. Grain crops are desirable.

Other spinach and beet diseases

Drop	(See lettuce, page 457)
Downy-mildew	(See carrots, page 436)
White-smut	(See onions, page 407)
Scab	(See potato, page 469)

Anthracnose
Phyllosticta leaf-blight
Black-mold
Root-knot

CHAPTER XXVII

PESTS OF THE CABBAGE FAMILY

KEY FOR DIAGNOSING CABBAGE FAMILY TROUBLES

Foliage yellow

Aphis, red-spider (during prolonged droughts), club-root, black-rot, black-leg, yellows, wilt, ring-spot.

Foliage spotted or mottled

Leaf-miner, black-rot, leaf-spot, drop, rust, mildew, black-mold, ring-spot, anthracnose, bacterial-blight, onion-thrips, sucking insects.

Foliage eaten

Cabbage-worm, cabbage-looper, diamond-back moth (shot-hole worm), webworm, zebra-caterpillar, cabbage-curculio, turnip-beetle, cutworm, army-worm, blister-beetle, flea-beetle, slugs, onion-thrips.

Stalks or stems injured

Cabbage-curculio, cabbage-seed-stalk weevil, cabbage-maggot, stem-canker, stem-rot, drop, black-leg.

Roots eaten

Cabbage root-maggot, seed-corn maggot, radish maggot, cabbage-curculio, nematodes (eel-worms), wire-worms, root-aphis.

Roots injured or enlarged

Club-root, root-rot, soft-rot, root-knot, scab (radish), Phoma-rot.

IMPORTANT CABBAGE FAMILY PESTS

No regular spraying is essential in growing plants in this family. Outbreaks of insect pests are sporadic during the season, and the sprays are not applied until the insects actually appear. Diseases are combated by the use of clean seed,

sterilization of seed and seed-bed, and crop rotation. In planning rotations, no two members of the cabbage family should follow each other on the same ground.

The presence of yellow or white cabbage butterflies may be taken as an indication of the quantity of cabbage-worms likely to appear later in the season, and control measures may be planned.

Fig. 179.—Cabbage-worm.

Imported cabbage-worm, cross-striped cabbage-worm, pot-herb butterfly, southern cabbage butterfly, and cabbage-looper

These greenish or gray-green worms (Fig. 179) feed on the under sides of the leaves and burrow into the heads in search of the tenderest foliage. There are several broods. The presence of yellow or white cabbage butterflies indicates a coming infestation of worms. Arsenical sprays or dusts applied whenever the worms appear are effective. A dust made of 5 parts of flour with high gluten content (12 per cent) and 1 part of lead arsenate is very effective.

Cabbage webworm, garden webworm

Three or four generations of yellowish-gray caterpillars feed on the under sides of leaves and burrow into leaf-stems and heads, covering the feeding ground with a silken web. They often attack the head or heart of the plant and kill it outright. Arsenical sprays or dusts soon after transplanting and before the web is spun will control them. When serious, all refuse should be destroyed after harvest.

FIG. 180.—Cabbage aphis.

Cabbage aphis, turnip aphis (Fig. 180)

These grayish-green aphis attack a wide range of plants, sucking out the juices and dwarfing or destroying them. Spraying with ½ pint of nicotine sulfate and 2 pounds of fish-oil soap to 50 gallons of water, or dusting with 1½ to 3 per cent nicotine dust as soon as the lice appear and before the leaves are curled, will control them. If transplants are infested they should be dipped before setting out in a solution of 6 pounds of fish-oil soap in

50 gallons of water, taking care to prevent roots from being wetted with the dip.

Cabbage root-maggot (Fig. 181), *seed-corn maggot, western radish maggot*

A small white maggot bores into the roots of cruciferous plants, causing them to wilt in the heat of the day, and finally to die or remain stunted and sickly. Tar-paper cards around young cabbage plants at transplanting time prevents egg deposition on this crop. A half teacupful of corrosive-sublimate solution, made by dissolving 1 ounce of the corrosive sublimate in 10 gallons of water, should be poured around the stems of the plants four days after they are set in the field, and another application eight to ten days later will control this pest. Carbolic-acid stock emulsion (see page 65) diluted 1 to 30 of water, applied weekly at the rate of ½ teacupful to a plant, starting with transplanting, will kill the eggs. Late cabbage and radish seed-beds are sometimes screened with cheesecloth.

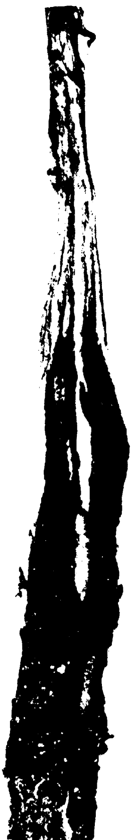


Fig. 181.—Cabbage maggot in stems and root.

Harlequin cabbage-bug, green soldier-bug

These flat evil-smelling bugs, in adult and nymph stages, suck the juices from the plants, poisoning them and causing them to wilt and turn brown as if scalded. The bugs are controlled by sanitation, burning hedgerows and piles of rubbish in the spring, and the use of trap crops or trap boards by which they can be destroyed readily. A torch is occasionally used. The passage of a flame sufficient to burn the antennæ and legs

results in the death of the insect. Slight injury may be done to the tips of the cabbage leaves, but the plants readily outgrow this injury.

False chinch-bug

Grayish-brown bugs suck the juices from plants and cause them to wilt, turn brown, and die. Sanitation and the use of ½ pint of 40 per cent nicotine sulfate and 2 pounds of soap to 50 gallons of water when they appear will control them.

Fall army-worm, yellow-striped army-worm, beet army-worm

Large greenish-black worms, frequently moving in large numbers—hence the name—eat all kinds of green foliage. Poi-

Fig. 182.—Cutworm injury on cabbage plant (right); uninjured plant at left.

soned baits (see page 46) cast about the patch, hand-picking, and barrier furrows with the straight side next to the field to be protected, are common methods of control. If the barrier furrow has frequent post holes dug in it, the worms will collect in them and can be killed with kerosene.

Cutworms (nineteen species)

Smooth naked caterpillars feed on nearly every green foliage and frequently cut succulent plants off at the surface of the ground by feeding at the base—hence the term cutworm (Fig.

182). Cardboard or tin cylinders sunk around tomato or similar plants will prevent the worms from reaching them. Poisoned baits are very effective, particularly if applied a few days before the young plants come up or are set out. The cutworms winter over in the soil, and they come out just about the time the young plants are ready to be put out. On young cutworms arsenical sprays are effective.

Fig. 183.—Club-root of cabbage.

Flea-beetle (*eleven species*)

Small shiny dark-colored beetles feed on the foliage of a wide range of plants, riddling the leaves with small pits or holes, which cause them to wilt and fall. The larvæ of the beetles hibernate in hedgerows and rubbish. When disturbed they jump a foot or more in the air and usually out of danger—hence the name.

Control is secured by using bordeaux mixture as a deterrent or repellent, and either 1½ pounds of powdered lead arsenate or 1 pound of paris green to 50 gallons of bordeaux as a poison, spraying whenever the beetles become numerous. Lime, land plaster, or common road dust applied with a hand-bag duster will also repel them. Seed-beds can be screened. If beetles are a serious menace to newly transplanted plants, they can be dipped in the above solution before being transplanted.

Blister-beetle (*seven species*)

Elongated long-legged beetles occasionally attack crops in

swarms, defoliating the plants. They usually feed in colonies. Control is secured on tender plants by screening and hand-picking. On field crops, or plants resistant to spray, 2 pounds of powdered lead arsenate or 1 pound of paris green and a

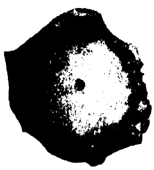


FIG. 184.—Black-rot in stem of cabbage.

FIG. 185.—Downy-mildew on cabbage leaf.

pound of slaked lime to 50 gallons of water, are used. In Arkansas equal parts of sodium fluosilicate and hydrated lime dusted on alfalfa and soybeans gave very effective control of blister-beetles.[1]

Club-root (Fig. 183), *root-knot*

Sickly looking plants wilt on hot days, and the root is swollen and deformed by the action of a slimy mold. Small swellings are found on lateral roots, particularly in root-knot. Control is secured by using new land, lime, and disease-free plants. Any slight nodule or swelling on roots of seedlings indicates the presence of this disease, and all the plants in that bed should be discarded. Spraying is ineffective.

[1] Ark Agr. Exp. Sta. Bull. 201. 1925.

FIG. 186.—Black-leg of cabbage.

Black-rot, stem-rot (Fig. 184)

Yellowed leaves with burned edges and blackened veins, premature defoliation, particularly of lower leaves, and stems or stalks showing a black ring on being cut open are indications of black-rot.

Clean seed should be planted. Seed should be sterilized with hot water (see page 500) or with corrosive sublimate solution, 1 to 1,000, for fifteen minutes. All diseased plants should be destroyed and fields cleaned up after harvest.

Damping-off

Soft, water-soaked, yellowish, wilted seedlings with decayed stems at the surface of the ground are injured by various

damping-off fungi. Careful regulation of ventilation, temperature, and soil moisture, soil sterilization, and thinner planting are methods of control.

Downy-mildew (Fig. 185)

This disease causes whitish downy patches on the under sides of the leaves, causing them to yellow and wilt. Bordeaux mixture applied when the disease appears, followed by additional applications when the weather is damp, will control it.

FIG. 187.—Cabbage yellows.

Black-leg (foot-rot) (Fig. 186)

Oval, depressed, light-brown lesions containing tiny black spots, near the base of the stem, appearing either in the seed-bed or in the field, may be caused by black-leg. The canker enlarges until the stem is

girdled and turns black. Sterilization of seed as for black-rot and of the seed-bed is recommended, and at least a three-year rotation should be practiced, refuse stalks and heads being destroyed after harvest.

Wilt or yellows (Fig. 187)

Yellow stunted seedlings or field plants which drop their leaves readily, resulting in the death or defoliation of the plant, are caused by wilt. The use of good seed and resistant varieties, new land, and soil sterilization are recommended.

Bacterial leaf-spot (*Macrosporium leaf-spot*)

Small purple-gray spots, coalescing sometimes to involve the whole leaf, causing it to yellow and drop off, are caused by leaf-spot. When disease appears, one should spray with 4-4-50 bordeaux and pull out and burn infested plants.

White-rust

White raised lesions appear on the leaves and flower organs, causing them to become abnormal and distended. Crop rotation and burning of all crop remnants are advised.

CHAPTER XXVIII

PESTS OF THE CARROT FAMILY

KEY FOR DIAGNOSING CARROT FAMILY TROUBLES

Foliage yellow

Blight.

Foliage spotted or mottled

Leaf-spot, late blight, early blight.

Foliage eaten

Black swallowtail butterfly larva, celery leaf-tyer, looper, web-worm, leaf-miner, cutworms, army-worm, blister-beetle, flea-beetle, slugs. Sucking insects: tarnished plant-bug, negro-bug, aphis.

Roots injured

Rust-fly maggot, carrot-beetle, nematodes (eel worms), wire-worm, soft-rot, Rhizoctonia root-rot.

Stalks injured

Celery leaf-tyer, negro-bug, parsley-stalk-weevil, late blight early blight, lettuce-drop, pink-rot.

CARROT FAMILY PESTS

No regular spray schedule is advised for all members of this group, but celery needs special treatment for early and late blight, seven or eight applications of 5-6-50 bordeaux mixture being made. The first should be applied when the plants are about an inch high in the seed-bed, and the second a few days before transplanting, and beginning after the plants are about five or six inches high sprays are applied at intervals

of seven to ten days until a week previous to harvest. This usually involves about five or six sprays.

The use of resistant strains is important in growing celery. White Plume and Easy Blanching are more resistant to heart-rot than the Golden Self-Blanching variety. In Michigan a strain of Golden Self-Blanching celery that is 90 per cent resistant to yellows has been developed. Aphids are a common pest of this family of plants, and nicotine sprays or dusts are used in combating them when they appear.

FIG. 188.—Celery leaf-typer at work in stalk.

Celery leaf-tyer (Fig. 188)

A small green caterpillar webs celery, and sometimes spinach, and beet leaves together and feeds on them. It is principally a greenhouse pest, and can generally be controlled by using arsenical sprays at standard strengths. Use of arsenicals in the field is inadvisable because of danger of the poison being carried to market.

Carrot rust-fly

A tiny maggot feeds on the tips of roots in the early spring, making rusty burrows which ruin carrots and parsnips, and causing roots to decay. Plants turn yellow, are stunted, and some die. A second brood does injury in late summer. Seed-bed sterilization will kill the larvæ and pupæ. Carbon bisulfid has lately been used successfully for this purpose.

Carrot beetle

Small beetles gnaw holes in roots and underground stems, while larvæ do some damage. Clean farming and rotation are the only combative measures known.

Tarnished plant-bug

This flat brown inconspicuous bug about ¼ inch long and the young nymphs suck the juices from the leaves, stems, and seed-stalks, deforming them and usually causing them to look burned. Clean farming and burning of hedgerows and trash where the insects hibernate in the winter are advised.

Negro-bug

A small black stink-bug sucks out the juices from leaves and stalks, causing the leaves to die. Celery especially is

FIG. 189.—Early blight on celery.

stunted and deformed. Spraying with ½ pint of 40 per cent nicotine sulfate and 2 to 3 pounds of soap to 50 gallons of water when the bugs appear will control them.

Other carrot family insects

Cabbage-looper	(See cabbage, page 424)
Aphis	(See cabbage, page 425)
Cutworms	(See cabbage, page 427)
Army-worms	(See cabbage, page 427)
Blister-beetle	(See cabbage, page 428)
Garden spring-tail	(See melons, page 450)
Slugs	
Black swallowtail butterfly.	

Late blight, early blight (Fig. 189)

These serious celery diseases cause irregular spots on the leaves which wither and dry up, rendering the stalk worthless. Spraying with a 5-6-50 bordeaux mixture starting with two applications in the seed-bed and one every week to ten days in the field will control these. One should use high pressure and fine mist, and observe weather conditions so as to make the spray applications just ahead of rainstorms.

FIG. 190.—Bacterial leaf-spot of celery.

Downy-mildew

Yellow spots appear on upper surface of leaves with mycelial web on corresponding lower surface, spots later turning dark brown and if numerous killing the leaves. Allowing plenty of space between plants and avoiding shading will do much to control this disease.

Leaf-spot (Fig. 190)

Dull brown patches on the leaf, caused by this disease, will be controlled by spraying as for early and late blight.

Yellows

Celery plants become yellowish and stunted, and tissues brittle and bitter, with reddish tissue in the crown. The use of resistant varieties is the only known method of control.

Other carrot family diseases

Drop..........................	(See lettuce, page 457)
Soft-rot	Rust
Phoma root-rot	Black-heart
Mosaic	Pink-rot

CHAPTER XXIX

PESTS OF THE CORN FAMILY

KEY FOR DIAGNOSING CORN FAMILY TROUBLES

Foliage yellow

Root-aphis, corn root-worm, stalk-borer, corn-borer.

Foliage spotted

Smut.

Foliage eaten

Spotted cucumber-beetle, cutworms, army-worms.

Stalks injured

Stalk-borer, European corn-borer, smut, Japanese beetle.

Ears injured

Corn ear-worm, root-aphis (if shriveled nubbins are produced), European corn-borer, smut, Japanese beetle.

Roots eaten or injured

Root-aphis, corn root-worm, white-grubs.

CORN FAMILY PESTS

No spraying is done for corn troubles, although attempts have been made to use this method for controlling ear-worm. Sanitary measures, such as keeping hedgerows clean, are beneficial, and spraying border weeds to keep down the root-worm and stalk-borer is sometimes practiced.

Corn ear-worm (Fig. 191)

A dark, large, striped worm feeds on the kernels and silk

on the growing ear of both sweet and field corn, and on the tomato fruit, leaves, and stem. No satisfactory control methods are known. Fall and winter plowing of infested fields and adjoining ground as far as possible are advised. The New Jersey Agricultural Experiment Station advises dusting with 50-50 mixtures of lead arsenate and sulfur immediately after the silk appears, and perhaps two more applications between that time and picking. Application is best made with a hand sifter. Tomatoes are sprayed with $1\frac{1}{2}$ pounds of powdered lead arsenate in 50 gallons of water. Crop remnants are destroyed.

FIG. 191.—Corn ear-worm.

Corn root-aphis (Fig. 192)

Infestation of roots by these lice cause the plant to appear yellowish or reddish, sometimes bearing only nubbins instead of ears, due to weakening through loss of sap. Injury is usually worst in low ground

and is more often noticeable in small areas or patches throughout the field.

Deep plowing and thorough disking to break up ant nests and scatter aphis eggs, fertilizing and cultivating the crop to stimulate a heavy growth of the plant, and rotating crops so that corn does not follow corn are recommended.

FIG. 192.—Corn root-aphis on stalk and foliage.

Corn root-worms: southern, western, Colorado

Corn plants, particularly in low spots, frequently look yellowish and are easily blown over or broken off by the cultivator, due to the attack on the stem and root by these worms. Two generations occur. The adults feed on fruit of the melon family, plants of the cabbage, asparagus, bean, potato, and many other families, and on blossoms of fruit-trees.

Late planting of corn and the use of well-drained land will hold this pest in check on the crop, while the methods employed in combating the striped cucumber-beetle will control it on other plants (see melon, page 445).

Cornstalk-borers (larger and lesser)

When corn plants become distorted and dwarfed, turn yellow, and break off well above the ground, the cause may

usually be attributed to cornstalk-borers which feed in the lower part of the stems. Crop rotation is the only method known which will reduce injury done by this insect. Destruction of corn stubble also helps, especially when corn is to follow corn.

European corn-borer

This new pest from Hungary is prevalent in New England, New York, Michigan, Ohio and Indiana, and in 1927 was

FIG. 193.—Japanese beetle in sweet corn tassles.

reported in Illinois and is alarming all corn-producing sections. The larvæ, which are white grubs about ¾ inch long, enter the plant and feed on the inner tissues in stalk, cobs, and

sometimes the roots, destroying the plant. No control methods are known, but the damage may be restricted by cutting not higher than three inches from the ground and lower if possible; cutting early; destroying all crop residues by burning or deep plowing; shredding all stalks for feeding, as for ensilage; burning uneaten parts of stalks which have been fed without shredding; screening the corn crib; and finally, obtaining all ear corn from uninfected areas.

FIG. 194.—Corn smut.

Japanese beetle (Fig. 193)

A beautiful shining bronze-green beetle about ⅜ inch long, with two white dots on the abdomen just below the tips of the brown wing-covers, appears in early summer in the Middle Atlantic states and feeds in the ears, and on the tassels and leaves. Grapes, cherries, peaches, apples and other fruit, foliage, and vegetables are also attacked. Repellent sprays, made of 3 pounds powdered lead arsenate, 1 pound flour (12 per cent gluten), 5 pounds hydrated lime and 50 gallons of water will keep the beetle from foliage. No method of preventing attacks in the ear have been devised. Natural enemies are being imported from Japan to aid in control.

Other corn family insects

Cucumber-beetle .... (See melon pests, page 445)
Flea-beetle .... (See cabbage, page 428)
Blister-beetle .... (See cabbage, page 428)
Cutworms .... (See cabbage, page 427)
Army-worms .... (See cabbage, page 427)
Cabbage webworm .... (See cabbage, page 425)
False chinch-bug
Wire-worm
Seed-corn maggot
Brown fruit-chafer
Stink-bugs

Bacterial-wilt

A drying out and whitening of the tassel and later of the basal leaves, and a dwarfing and finally the death of the plant are caused by bacterial-wilt. When stems of affected plants are cut, a yellow slime oozes out. Seed should be secured from disease-free sources and disinfected with formaldehyde (see page 500). The use of resistant varieties and crop rotation are also beneficial.

Smut (Fig. 194)

Whitish glossy boils on leaves, stalks, tassels, or ears, bursting to loose a black ugly mass of powdery spores, are caused by smut. Destruction of boils as they appear, before they burst, and vigilance to avoid the use of manure from animals fed with smutty stover or grain, will help to check this disease.

Other corn family diseases

Root-rot
Stalk-rot
Ear-rot

CHAPTER XXX

PESTS OF THE CUCUMBER FAMILY

KEY FOR DIAGNOSING CUCUMBER FAMILY TROUBLES

Foliage yellow

Leaf-spot, mosaic, wilt, downy-mildew, aphis, anthracnose, yellows, red-spider, bacterial-wilt.

Foliage curling

Aphis, squash-bug, plant-bug, leaf-blight, Cercospora leaf-spot.

Foliage spotted

Leaf-blight, leaf-spot, anthracnose, mosaic or little-pickle, Macrosporium blight (Fig. 195), Alternaria leaf-spot.

Foliage eaten

Pickle-worm, striped cucumber-beetle, flea-beetle, melon-worm, squash-beetle, garden spring-tail, army-worm, cut-worms, blister-beetle.

Leaves dying

Squash-bug, plant-bug, aphis, garden spring-tail, mosaic or little-pickle, mildew, anthracnose. Sucking insects: aphis, squash-bug, red-spider, mite, plant-bug.

Stems or roots injured

Squash-vine borer, nematodes (eel-worms), cucumber-beetle, sooty-mold, bacterial-wilt, southern blight, anthracnose, vine-wilt or yellows.

Vines dying

Cucumber-beetle, squash-bug, squash-vine borer, bacterial-wilt, vine-wilt or yellows.

Blossoms injured

Melon- and pickle-worm.

Fruit injured

Squash-vine borer, melon- and pickle-worms, soft-rot, fruit-rot, southern blight, mosaic or little-pickle, stem-end rot, anthracnose, blossom-end rot, Fusarium rot (Fig. 196).

CUCUMBER FAMILY PESTS

Three pests—the striped cucumber-beetle, blight, and plant-lice—make a heavy spray schedule essential to successful culture of cucurbits in most localities. Cucumber-beetles attack the plants as they come up and must be controlled during the early life of the crop, while blight, appearing usually when the plants are about touching in the field, requires the application of possibly five sprays of 3-4-50 bordeaux mixture. The control of cucumber-beetles results in control of bacterial-wilt, as these beetles are the sole carriers of this disease. Aphis must be combated with nicotine as they appear. The squash is less troubled by pests than the melon and cucumber.

Cucumber-beetles (Fig. 197): *striped, western, twelve-spotted, belted*

These beetles feed voraciously on the leaves and stems of all the cucurbits, just as they come up, weakening or killing them outright, while the larvæ burrow into the stems below and above ground. The striped cucumber-beetle is the sole carrier of bacterial-wilt. The new summer brood of beetles also gnaws holes in the rind of the fruit. A 3-4-50 bordeaux mixture with 1½ pounds of powdered lead arsenate added proves an effective deterrent, and some beetles will be poisoned. Two per cent nicotine dust has lately been found effective, if applied with a hover or hood. A dust made of one part of calcium arsenate to 20 parts of land-plaster, applied with a burlap

bag duster, is also effective. Hydrated lime has been found to stunt the growth of the plants. Trap crops of squash around melons or cucumbers are advised, and thorough cultivation or

Fig. 195.—Macrosporium blight on watermelon.

fertilization to stimulate rapid growth. Markovitch [1] reports excellent control of these insects by dusting the plants early in the morning with "extra light" sodium fluosilicate.

[1] Markovitch, S., Tenn. Agr. Exp. Sta. Circ. 1. 1926.

Squash-bug (Fig. 198), *horned squash-bug* (*stink-bugs*)

These large brown vile-smelling bugs suck the juices from young plants and inject a poison which often kills the plants outright, while the feeding of the nymphs on the under sides of the leaves causes them to curl, wilt, and die.

Adults may be killed by burning trash, hedgerows, and woodlands in the late winter, by clean farming, and by trapping

FIG. 196.—Fusarium rot on cucumber.

the bugs under boards in the melon patch. They will congregate under such boards in the daytime and may be killed easily. Hand-picking is advised. Nymphs may be killed by spraying with ½ pint of 40 per cent nicotine sulfate and 2 pounds of fish-oil soap to 50 gallons of water when they appear.

Leaf-footed plant-bugs (*northern and western*)

The adults have peculiar leaf-shaped hind legs, hence the name. Adults and larvæ damage the plants as do the squash-bugs. Destruction of the yellow thistle, an important food plant of this pest, hand-picking, and clean farming will reduce the adults, while the nymphs may be controlled by nicotine and soap as for squash-bugs.

Squash-vine borer (Fig. 199)

This brown-headed white caterpillar burrows in the stems, roots, leaf-petioles, and fruit, usually killing the vine. Rotation of crops, destruction of vines immediately after harvest, heavy cultivation and fertilization, deep spring plowing to expose the cocoons, and cutting the borers out with a knife are recommended. Worthley[1] reports almost complete control from spraying with nicotine sulfate (40 per cent nicotine) diluted 1 gallon to 100 gallons of water. Four applications are applied at weekly intervals, starting when the tiny reddish - brown eggs, laid singly, are found on the stalks. This occurs about July first in Massachusetts. This is an expensive spray, the nicotine dilution of 1 to 100 being far stronger than is required for other insects.

FIG. 197.—Striped cucumber-beetle injury to melon seedling.

[1] Worthley, H. N., Mass. Agr. Exp. Sta. Bull. 218. 1923.

Pickle-worm (Figs. 200, 201), *melon-worm*

The moths lay eggs on the blossoms and the caterpillars feed in the blossom, fruit, and stems, sometimes entering as

FIG. 198.—Squash-bug.

many as two or three fruits. Decay usually ensues. Sprays are ineffective. Trap crops, burning of crop residues, rotations, and early planting are advised.

Melon aphis (Fig. 202), *squash aphis*

These aphis, varying in color from yellow and green to

very dark green, appear on the under sides of the leaves of curcurbits throughout the season, soon covering the leaves and causing them to yellow, wilt, or die, often killing the vines. Control is effected by spraying with ½ pint of 40 per cent

Fig. 199.—Borer in squash root.

Fig. 200.—Pickle-worm injury on cucumber.

nicotine sulfate and 2 pounds of fish-oil soap in 50 gallons of water, or by dusting with 1½ to 2 per cent nicotine dust.

Garden spring-tail

Yellow and purple wingless insects eat small holes in the leaves. When disturbed, they throw themselves into the air by means of forked tail-like appendages. Injury is sometimes severe enough to stunt or kill the plant. A 1½ to 2 per cent nicotine dust is an effective insecticide.

Other cucurbit insects

Squash ladybird ..	(See Mexican bean-beetle, page 410)
Army-worms	(See cabbage, page 427)
Cutworms	(See cabbage, page 427)
Blister-beetles	(See cabbage, page 428)
Flea-beetles	(See cabbage, page 428)
Garden webworm	(See cabbage, page 425)

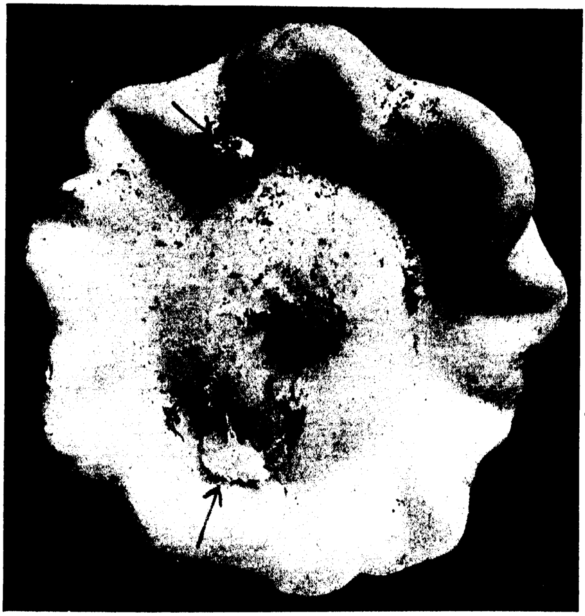


FIG. 201.—Melon-worm injury on squash. The piles of light yellow frass block the burrows made by the worm.

Bacterial-wilt (Fig. 203)

The leaves and finally the entire plant wilt and die from the attack of this bacillus which is spread through the injuries

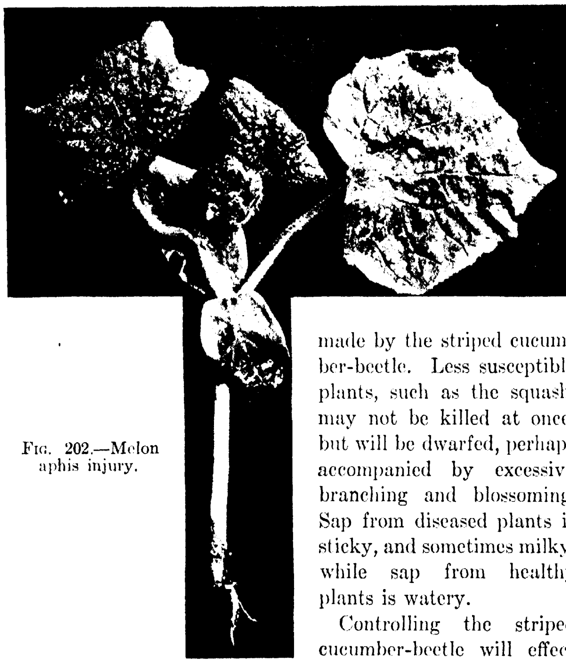


FIG. 202.—Melon aphis injury.

made by the striped cucumber-beetle. Less susceptible plants, such as the squash, may not be killed at once, but will be dwarfed, perhaps accompanied by excessive branching and blossoming. Sap from diseased plants is sticky, and sometimes milky, while sap from healthy plants is watery.

Controlling the striped cucumber-beetle will effectively check bacterial wilt. (See page 445.) When plants show symptoms of wilting they should be removed and burned.

Soft-rot, fruit-rot

Variable moisture conditions cause cracks in melons, through which the soft-rot bacillus gains entrance. The rot is soft and has an offensive odor. Irrigation in dry weather, turning melons to expose all sides to the light, spraying with bordeaux mixture in wet weather, and burning of crop residues are recommended.

Leaf-blight, Cercospora leaf-spot

Small, round, brown, dry spots made up of concentric rings cause the leaves to curl and fall, leaving bare vines and exposed fruit, interfering with the ripening of the melons. Cercospora leaf-spot is more angular than leaf-blight spot. A 3-4-50 bor-

FIG. 203.—Bacterial-wilt on cucumber.

FIG. 204.—Mosaic on cucumber.

deaux mixture, applied by driving the sprayer over the vines when the vines begin to touch is effective. Crop rotation and the use of resistant varieties are also recommended.

FIG. 205.—Anthracnose on cucumber stem and leaf.

Mosaic (white or little-pickle)

A yellow mottling appears at the stem-end of the fruit, and later light colored areas are found all over the fruit which becomes distorted (Fig. 204). The leaves are mottled, dwarfed, and distorted and die prematurely. The new leaves contract the disease and insects spread it. Insect attacks should be prevented and all infected plants burned.

Downy-mildew

Yellowish spots appear on the leaves, causing them to wilt and die. The infection spreads rapidly, a patch occasionally becoming a total loss in ten days. Bordeaux mixture, applied at the first sign of the disease, with high pressure and with at least four nozzles to the row, will control it.

Wilt or yellows (See bean and pea, page 417).

Anthracnose (Fig. 205)

Dark circular spots on the leaves, becoming so numerous as to coalesce at times, causing the death of the leaf, water-soaked spots on stems, causing them to turn brown and crack, and deep, circular, salmon-pink depressions on the rind of the fruit indicate anthracnose. The disease spreads in shipment also. Spraying with a weak 3-4-50 bordeaux mixture, destruction of crop remnants, and rotation are the control methods to be employed.

Other cucurbit diseases

Angular leaf-spot
Mycosphærella wilt and black-rot
Macrosporium blight
Fusarium wilt
Scab
Cercospora leaf-spot

CHAPTER XXXI

PESTS OF THE LETTUCE FAMILY

KEY FOR DIAGNOSING LETTUCE FAMILY TROUBLES

Foliage yellow

Downy-mildew, anthracnose, bacterial-wilt, aphis, carrot rust-fly maggot.

Foliage spotted or mottled

Anthracnose, bacterial-wilt.

Foliage or head decaying

Bottom-rot, lettuce-drop, gray-mold, downy-mildew.

Foliage eaten

Cabbage-worm, cabbage-looper, army-worms, cutworms, cucumber-beetle.

Stem or roots injured or dying

False chinch-bug, gray-mold, bacterial rosette.

IMPORTANT LETTUCE FAMILY PESTS

No regular spraying schedule is advised to control pests attacking the lettuce-family plants. The most general means of control are by seed-bed sterilization, particularly for lettuce-drop in crops for transplanting, soil sterilization in greenhouses and small gardens, crop rotation, and the use of resistant varieties in field planting. Some spraying with 3-4-50 bordeaux mixture is occasionally done just before and just after transplanting to control downy-mildew, while aphis are controlled by the use of nicotine dust when the insects appear. Arsenical sprays are not recommended for use on lettuce. Recent work has shown that poisoned baits are of some value against cabbage-looper on the lettuce crop.

Bottom-rot

Rust-colored slightly sunken lesions appear on the petioles, and slimy, dark brown, rotten spots on the foliage, and decay spreads rapidly until the entire head is a shiny dark brown mass. Soil sterilization is recommended for small gardens and greenhouses. The use of resistant varieties, crop rotation, and good drainage are recommended in field control. Big Boston is the variety most affected.

Bacterial-blight

Numerous water-soaked spots attack the outer leaves, which soften and dry up. Crop rotation and burning of diseased plants and crop remnants are advised.

Downy-mildew

Leaves turn yellow and a grayish downy web appears on the under sides, and finally the leaves wilt. Soil sterilization, clean cultivation, ventilation, and regulation of soil moisture are advised. Spraying of lettuce is not generally recommended, except for an application of 3-4-50 bordeaux mixture to both upper and lower leaf surfaces at least two or three days before transplanting and again two or three days afterwards.

Lettuce-drop

This is a very serious disease which causes first the outer leaves and then the inner or whole plant to droop and appear as if scalded by boiling water. A white cottony fungus is found on the under sides of lower leaves. In the greenhouse, soil sterilization, frequent inspection and immediate pulling of diseased plants, and disinfection of the spot where they stood with copper-sulfate solution, made with 1 pound bluestone to 7 gallons of water, are advised. In the field, crop rotation with plants not related to lettuce, shallow cultivation, good

drainage, and allowing plenty of room between rows will cut down trouble.

Septoria leaf-spot

Brown spots with tiny black pustules on them appear on the older leaves. Resistant varieties should be planted.

Other lettuce family diseases

Damping-off, bacterial rosette.

Lettuce family insects

Cabbage-looper	(See cabbage, page 424)
Garden webworm	(See cabbage, page 425)
False chinch-bug	(See cabbage, page 427)
Spotted cucumber-beetle	(See cucumber, page 445)
Cutworms	(See cabbage, page 427)
Army-worms	(See cabbage, page 427)
Aphis	(See cabbage, page 425)

CHAPTER XXXII

IMPORTANT MUSHROOM PESTS

Bacterial-spot

Caps develop yellow spots while the mushroom is in the button stage or later. Spots turn brown, making the mushroom unsightly and reducing the market value. Taubenhaus recommends fumigating the beds before planting the spawn with $1\frac{1}{2}$ pounds of sulfur to each 1,000 cubic feet of the house.

Mycogone

Tubercles form on the cap and fluffy white growths develop on the gills, distorting the mushroom and finally causing it to decay. In severe cases, large distorted masses with coatings of white fungus grow on the mushroom, later decaying and giving off a disagreeable odor.

Diseased plants should be rogued out and burned immediately as they appear. At the end of the season, beds should be cleaned and the house and all equipment fumigated with formaldehyde gas for twenty-four hours.

Mushroom maggots (gnats)

These tiny insects are particularly troublesome in the summer. The gnats fly into the house through openings, lay eggs in the mushrooms or in the soil at the base, and the larvæ feed on the mushrooms, rendering them unmarketable. They may be reduced by holding the temperature of the mushroom cellar to 55° F., screening openings, and properly composting the manure used. Where infestation is severe, fumigation with tobacco is recommended.

Sow-bugs

Grayish oval "wood-lice" about ½ to ¾ inch long are occasionally introduced into the cellar in compost. They feed on the mushrooms as soon as the first buttons appear. Fumigation of the house with hydrocyanic gas, or the use of poisoned bait made by dipping raw potato or raw apple in paris green or lead arsenate, is recommended.[1]

Spring-tail

These common insects feed on the gills and caps of the mushrooms. Fumigation as for sow-bugs, or dusting the beds with Pyrethrum or quicklime, is recommended for controlling them.

Mites

These minute insects attack both spawn and mushrooms, and when once established are almost impossible to control. The beds should be cleaned out and the compost removed or sterilized, and the house thoroughly sterilized with carbolic-acid wash. The mites will be less troublesome at low temperatures.

[1] U. S. Dept. Agr. Farmers' Bull. 789.

CHAPTER XXXIII

PESTS OF THE POTATO FAMILY

KEY FOR DIAGNOSING POTATO TROUBLES

Foliage yellow

Rhizoctonia, black-leg, aphis, leaf-spot, mosaic (Fig. 206), wilt, early and late blight, tip-burn, hollow-stem, leaf-hopper, stalk-weevil.

Foliage rolled and mottled

Mosaic, curly dwarf, leaf-roll, aphis, leaf-hopper, acid soil.

Foliage spotted

Early blight, late blight, mosaic, leaf-spot.

Foliage eaten

Potato-beetle, flea-beetle, cutworms, army-worms, blister-beetle.

Foliage dying

Tip-burn, early and late blight, Rhizoctonia (Fig. 207), wilt, stalk-borer, stalk-weevil.

Stems cankered or spotted

Rhizoctonia, black-leg, early blight.

Tubers or roots spotted or scabby

Black-leg, late blight, Fusarium dry-rot, powdery-scab, jelly end-rot, soft-rot, leak, stem end-rot, potato wart (black-rot) (Fig. 208).

Tubers or roots streaked or blackened within

Black-heart, brown-streak, wilt, hollow-heart (Fig. 209).

Tubers or roots wormy

Tuber-moth.

Fig. 206.—Potato mosaic, diseased and healthy shoots.

IMPORTANT POTATO PESTS

Alternaria and Septoria blight are distributed wherever plants of the potato family are grown. Bordeaux mixture, applied five times, is generally advised for controlling these. The addition of arsenate of lead or paris green to these sprays will kill the Colorado potato-beetle, while the addition of nicotine sulfate when aphis appear will control them. Thus two, or at most three, pests control the spraying done, and the other insects and diseases attacking the tops are incidentally taken care of. Potato-scab is controlled by seed treatment, by avoiding the use of fresh stable manure, and by maintaining soil acidity by applying sulfur. The other plants of this family require seed treatment for various troubles.

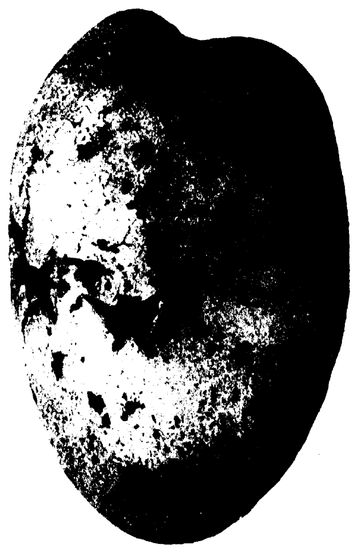


FIG. 207.—Rhizoctonia on potato.

Dusting is sometimes practiced, particularly in controlling aphis, but occasionally in combating blight. However, up to 1927, spraying has been more generally satisfactory, although the introduction of colloidal copper dusts adds a promising dry material. Three nozzles to a row are advised for spraying, one shooting down directly on the tops, and the other two being set low and aiming inward and a little upward.

Colorado potato-beetle

Orange and black striped beetles about $\frac{3}{8}$ inch long and larvæ a little larger than the beetles, varying from brick red to light salmon, with the black dots, feed ravenously on the leaves, defoliating the vines. Two generations with a long egg-laying period in each keep the beetles present from very early spring to late summer.

Fig. 208.—Potato wart. This disease was introduced from Hungary and is only found in Pennsylvania, West Virginia, and Maryland mining districts. Growers are advised to be on guard against it and to report first appearances to the agricultural authorities in the county or state. It is a terrible pest in Europe.

Control is secured by spraying with 1 pound of paris green or $1\frac{1}{2}$ pounds of powdered lead arsenate to 50 gallons of water, or in the bordeaux mixture. When arsenates are used alone with water, 1 to 2 pounds of hydrated lime should be added to prevent arsenical burning. Dusting with a mixture of 1 pound of paris green to 20 or 30 pounds of hydrated lime or finely sifted wood-ashes, or 1 pound of powdered lead arsenate to 15

pounds of hydrated lime or finely sifted wood-ashes, is a satisfactory method to use in the garden or on a small patch. The operator carries this mixture in a burlap bag along the rows, giving it a shake over each plant. Hand-picking is also practiced on a small scale. Lead arsenate should be used on tomatoes, eggplant, and peppers.

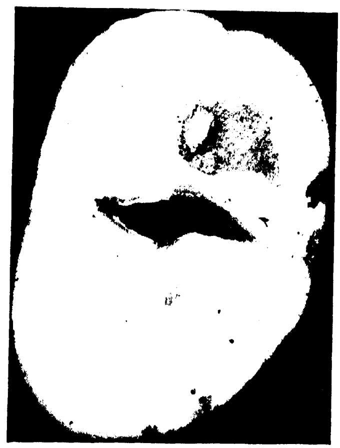


Fig. 209.—Potato hollow-heart.

Potato aphis

Green and occasionally pink plant-lice are found in great numbers on the under side and on the tips of the leaves, curling them, and dwarfing and sometimes killing the plant. The crop is much reduced when the attack is serious.

Control may be effected by spraying with ½ pint of 40 per cent nicotine sulfate to 50 gallons of bordeaux mixture, or if the latter should not be used, with 2 pounds of fish-oil soap to 50 gallons of water, whenever the lice appear. The nozzles should be directed up at the under sides of the leaves and considerable pressure employed. It requires approximately 100 gallons of material to an acre. Dusting with a 1½ to 3 per cent nicotine dust has recently been found fairly effective if a canvas trailer, or trough, covering the plants, is used on the machine when applying the dust. About 50 or 60 pounds of dust to the acre will be required.

Leaf-hopper (Fig. 210)

Considerable damage can be done by this small greenish insect which sucks the juices from the under sides of the leaves, causing the tips to turn brown as if burned, resulting

FIG. 210.—Potato leaf-hopper injury and nymphs.

in the injury commonly called "hopper-burn." Bordeaux mixture has been found to act as a satisfactory control. Nicotine, as applied for potato aphis, will also control leaf-hoppers.

Potato tuber-moth (Fig. 211)

A caterpillar about ½ inch long makes a small blotchy mine in the leaf, or stem, causing the leaf to die, and riddles the tubers with burrows, resulting in decay. This insect

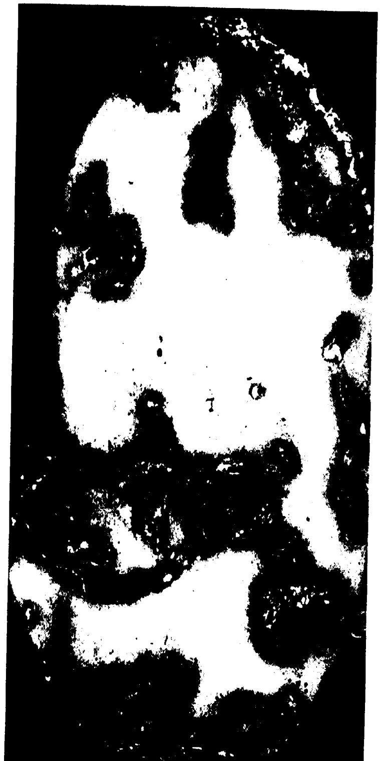


FIG. 211.—Tuber-moth injury on potato.

has become a very serious pest in the eastern shore of Maryland and Virginia.

Cory and Sanders[1] recommend the following precautions: (1) all potatoes badly infested in the spring should be destroyed; (2) keep the potatoes well ridged to avoid tuber infestation before harvesting; (3) dig before the vines are dead, if possible, but if harvesting is delayed until vines are dying, give adequate ridging; (4) spray or dust with arsenicals, or a combination of bordeaux mixture and arsenicals; (5) use mechanical diggers; (6) absolute clean-up of potatoes after each harvest; (7) allow no potatoes to stand exposed in the fields at night; (8) cover barrels with burlap as soon as filled.

[1] E. N. Cory and P. D. Sanders, *Jour. Econ. Ent.*, No. 2, 235-239 Vol. 19. 1926.

Other potato insects

Flea-beetle	(See cabbage, page 428)
Corn ear-worm	(See corn, page 438)
Cutworms	(See cabbage, page 427)
Army-worms	(See cabbage, page 427)
Blister-beetle	(See cabbage, page 428)
Cucumber-beetle	(See melon, page 445)
Stalk-weevil	
Stalk-borer	
Burdock borer	

Rhizoctonia (also called foot-rot, black-pox, canker, stem-rot, scurf, rosette)

Small black specks (fruiting bodies) appear on mature tubers, sometimes becoming 1/8 inch in diameter. Sprouts may be attacked at the tip with a reddish-brown rot, or girdled along the stem, causing new sprouts to start below the girdle. These in turn may be attacked and killed until finally the plant dies or remains stunted and yellowish. At other times the plant may grow abnormally large and set small aerial tubers along the stems (Fig. 213). In wet weather a white cobweb-like mycelium may appear around the base of the stem (Fig. 212).

Spraying does not control Rhizoctonia. According to Chupp [1] the use of disease-free seed, and seed treatment with corrosive sublimate (mercuric chlorid) are recommended. The seed should be immersed for one-half hour in solution of 4 ounces of corrosive sublimate in 30 gallons of water. Treatment should take place before cutting the potatoes. The solution should be between 45° and 70° F. in temperature. After treatment the seeds should be spread out in a thin layer to dry, and allowed to sprout in the light. Tubers with strong sprouts will come up quickly when planted, thus running less chance of becoming infected, while tubers with spindling sprouts can thus be eliminated before planting.

[1] Chupp, Chas., *Manual of Vegetable-Garden Diseases.* Macmillan, 1925.

Common scab (Fig. 214)

Spots of corky tissue develop on the tubers, reducing the yield and injuring the appearance and market value of the crop. These develop worse in alkaline soils. Control is effected by disinfecting seed potatoes with corrosive sublimate, cyanid of mercury diluted to make a 1 to 1,000 solution, or 1 pint of 40 per cent formaldehyde to 30 gallons of water (see page 498). The use of manure, especially from animals which have eaten scabby potatoes, and fertilizers which tend to make the soil more alkaline, increases scab, while acid phosphate, muriate of potash, and other acid fertilizers reduce it. In New Jersey, W. H. Martin has secured marked results from 500

FIG. 212.—Rhizoctonia lesion on potato stem.

FIG. 213.—"Little potato" form of Rhizoctonia.

to 800 pounds of sulfur to the acre. Crop rotation is also desirable.

Powdery-scab (Fig. 215)

This disease differs from common scab in that it makes galls on the rootlets, and the spots on the tubers are more circular and frequently contain black powdery spore masses. The same control methods as for common scab are advised.

Black-leg (Fig. 216)

Unthrifty, yellowish, undersized plants, exhibiting, when pulled out, a black stem near the seed potato, extending sometimes along the stem above ground, are suffering from black-leg. Seed disinfection as for common scab, as above, will control this trouble.

Late blight (Fig. 217)

This disease causes dark areas to appear on the under sides

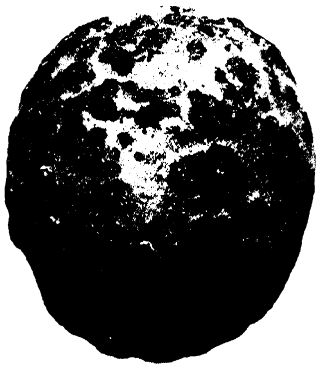


FIG. 214.—Potato scab.

FIG. 215.—Powdery-scab on potato.

FIG. 216.—Potato black-leg rot.

of leaves, which wilt and die. Tubers are often affected, the black spots extending under the surface and rotting, the potato yields are reduced, and occasionally crops are completely ruined. It is more severe in cool moist climates.

FIG. 217.—Late blight of potato.

Spraying with bordeaux mixture from three to six times during the season, starting when the plants are about six inches high and thenceforth depending on the climate and weather, is practiced. Usually in cool climates spraying every two weeks is sufficient, and less frequently in warm sections.

Fusarium wilt (Fig. 218)

Poor germination and poor stands, followed by a wilting of lower leaves and then the higher foliage, resulting frequently in the premature dying of the tops, are caused by Fusarium wilt. In the tubers a dark ring in the flesh, especially near the stem-end, indicates the disease.

Control may be secured by spraying with bordeaux mixture as for late blight.

Other potato diseases

Spindling sprout	Mosaic
Net necrosis	Black-rot
Black-wart	Jelly end-rot
Melters or leak	Stem end-rot
Silver-scurf	Powdery dry-rot
Root-knot	Black-heart
Yellow-dwarf	Phoma-rot
Leaf-roll	Brown-rot
Curly-dwarf	

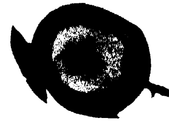


FIG. 218.—Stem-end browning due to potato wilt.

KEY FOR DIAGNOSING TROUBLES OF TOMATO, PEPPER, AND EGGPLANT

Foliage yellow or dying

Septoria leaf-spot, Alternaria fruit-spot, leafmold, bacterial leaf-spot, mosaic, streak, Fusarium wilt, Phoma rot, Phomopsis rot of eggplant, Verticillium wilt.

Foliage spotted

Septoria leaf-spot, Macrosporium blight, Alternaria fruit-spot, leafmold, bacterial spot, Phoma rot, Phomposis rot of eggplant.

Foliage eaten

Tomato-worm, potato-beetle, army-worm, cutworms, cabbage-looper, flea-beetles, erinose of tomato.

Foliage curled

Aphis, lace-bugs, plant-bugs.

Fruit spotted or rotting

Macrosporium blight, Alternaria fruit-spot, bacterial leaf-spot, streak, Phoma rot, Phomopsis rot of eggplant, anthracnose, blossom end-rot.

Stems cankered or discolored

Macrosporium blight, leafmold, streak, Fusarium wilt, Phoma rot, Phomopsis rot of eggplant, Verticillium wilt.

Stems eaten

Climbing cutworms, stalk-borers.

Roots injured or dying

Root-knot, Fusarium wilt.

TOMATO, EGGPLANT AND PEPPER PESTS

Spraying and dusting are indispensable practices in control of pests of tomato, eggplant and pepper. The tomato, in particular, is subject to a very wide variety of pests. According to Pritchard[1] of the United States Department of Agriculture, tomato leaf-spot, early blight and nail-head rust can be controlled by thorough spraying or dusting. Spraying has given best results. This practice should start when the plants are set in the field, and continue at weekly intervals until harvest.

FIG. 219.—Tomato-worm.

Sanitation is an important measure. Plowing under of infected plants in the fall gave markedly good results in controlling leaf-spot in particular, and it was found that early blight and nailhead rust were killed by being buried in the soil over winter.

The use of resistant varieties offers the greatest promise in disease control. The United States Department of Agriculture has developed several varieties of particular value to the

[1] Pritchard, F. J., *The Canning Trade*, Vol. 49, No. 14, Nov., 1925.

canning trade. Norton, Columbia, Nordukc and some others are highly resistant to Fusarium wilt and nailhead rust, and somewhat resistant to Septoria leaf-spot, early blight and leaf-mold. Marglobe, the most recent introduction, is a particularly desirable resistant variety.

Insect pests are effectively controlled by arsenical sprays or dusts. Lead arsenate is the safest form of arsenic. Paris green and calcium arsenate are likely to burn the foliage.

Tomato-worms (Fig. 219)

Caterpillars varying in color from green to dark brown feed ravenously on tomato foliage, becoming as long as 3 to 4 inches when full grown. They are marked with a diagonal stripe on each segment on the abdomen. They are readily detected by the damage to the vine, and the presence of their droppings. Hand-picking is most satisfactory in the garden. Spraying with lead arsenate at the rate of 2 to 3 pounds in 50 gallons of water or dusting with 3½ to 5 pounds of lead arsenate dust to the acre will control the insect in large fields. Control measures should start while the insects are small. Arsenicals should not be applied within two or three weeks of ripening.

Erinose of tomato

This tiny mite is injurious in the South, attacking the tips of the shoots and blossom-buds, stopping growth and preventing the setting of fruit.

Control is effected by spraying with a soda sulfur spray, or dusting with superfine sulfur.

Eggplant lace-bug

In the South the eggplant is frequently attacked by the grayish or light brownish lace-bug, which lays eggs on the under sides of the leaves and the nymphs hatching therefrom suck the juices from the tissues, sometimes injuring the plant so that fruit is not produced, or killing it altogether. Six generations occur before eggplant harvest in Virginia and two

afterward. Crosby and Leonard[1] advise spraying with 7 or 8 pounds of whale-oil soap to 50 gallons of water. The lower sides of the leaves must be hit.

Other tomato, pepper and eggplant insects

Corn ear-worm	(See corn, page 438)
Cabbage-looper	(See cabbage, page 424)
Leaf-footed plant-bugs	(See cucurbits, page 447)
Potato-beetle	(See potato, page 464)
Potato aphis	(See potato, page 465)
Cutworms	(See cabbage, page 427)
Army-worms	(See cabbage, page 427)
Flea-beetles	(See cabbage, page 428)
Blister-beetles	(See cabbage, page 428)
Eggplant tortoise-beetle	
Eggplant lace-bugs	

Septoria leaf-spot (Fig. 220)

Small circular water-soaked areas develop into spots with dark brown margins and sunken grayish centers on both surfaces of the leaves, sometimes becoming so numerous as to cover the leaves and kill the plant. Infection may occur any time during the life of the plant. This fungus may be distinguished from others by the appearance of tiny black fruiting bodies on the spots on the upper surface of the leaf. The disease is not as serious in cool climates as it is in the South.

The fungus is spread by cultural and harvesting operations. Therefore, sanitary measures are of importance. All crop remnants should be destroyed in the autumn if infected. Plant beds and equipment should be sterilized. Bordeaux mixture with resin fish-oil soap at the rate of 3 pounds to 50 gallons of the spray should be applied under high pressure. Two applications made to plants in the seed-bed and additional sprays once every ten days in the field will hold the fungus in check. Three nozzles to the row should be used, two shoot-

[1] Crosby and Leonard, *Manual of Vegetable-Garden Insects.* Macmillan, 1918.

ing up under the leaves. Copper soap dust has given favorable results in preliminary trials.

FIG. 220.—Septoria leaf-spot of tomato.

Macrosporium blight (nailhead rust) (Fig. 221)

Dark brown somewhat circular or oval spots appear on the leaves, particularly on the lower, shaded, and weaker foliage, sometimes involving most of the leaf. In enlarging, the spot

appears to form concentric rings of dead tissue. On the fruit circular, brown, depressed areas appear which later turn black in the center, giving a nailhead appearance. The discoloration extends to the center of the fruit, sometimes making it unsalable. Occasionally brown cankers are formed on stems.

Control is effected by using seed from healthy plants and by spraying as for Septoria leaf-spot.

Alternaria fruit-spot (Fig. 222)

This disease is frequently grouped with Macrosporium blight, and some plant pathologists do not distinguish between

FIG. 221.—Nailhead rust or Macrosporium blight on tomato.

them. Therefore, the gardener may have difficulty separating them.

The means of control are the use of disease-free seed of resistant varieties and by spraying as for Septoria leaf-spot.

Leafmold (Fig. 223)

Light green or yellowish areas on the upper surface, accompanied by a purplish mold on the lower surface, occasionally spread to involve the entire leaf, causing it to wilt and die. Old foliage is affected first. The spots appear sometimes on the stems of the fruit, causing the latter to fall.

Decreasing humidity in greenhouses is the best preventive method. Bordeaux mixture sprayed under high pressure is somewhat effective. Sulfur sprays are injurious to tomato plants.

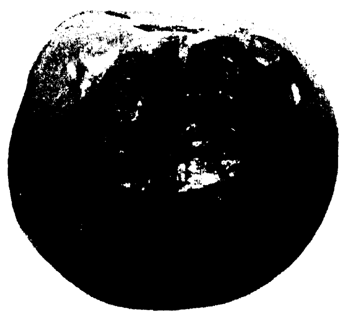


FIG. 222.—Alternaria fruit-spot on tomato.

Root-knot (Fig. 224)

Nematodes feeding on roots cause galls or enlargements to form. These galls rot, and the root dies, causing the plant to yellow and wilt.

Control is effected by sterilization, sanitation, and when possible, by crop rotation.

Bacterial-spot

Small water-soaked somewhat angular areas appear on the leaves. These often are greasy on the upper surface. Bacterial is distinguished from Septoria leaf-spot by size of spot, and angular outline. The leaves turn yellow and drop. On the fruit minute black raised spots, surrounded by a narrow water-soaked zone, appear. This stage is sometimes called scab. Spots coalesce to form large blotches.

Use of clean seed, seed treatment with 1 to 1,000 corrosive sublimate (1 tablet in a pint of water) for ten minutes and crop rotation, are recommended as helping to hold this bacterial disease in check.

Fusarium wilt (*sleepy disease*) (Fig. 225)

Stems show internal browning and lower leaves turn yellow

FIG. 223.—Cladisporium leafmold on tomato.

and the plant slowly wilts and dies. Roots show a black rot, and after dying the vines turn black and fruiting bodies of the fungus appear on the surface.

Use of resistant varieties such as Norton, Marvel, Columbia, Arlington, Louisiana Red and Louisiana Pink, are advised. Seed-beds should be sterilized, and clean seed used. Seeds should be treated in 1 to 3,000 corrosive sublimate (1 tablet to 3 pints of water) for five minutes.

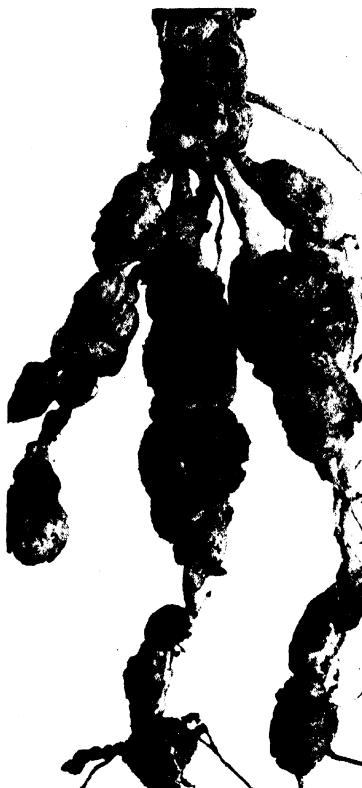


FIG. 224.—Root-knot on tomato.

Phomopsis blight of eggplant (Fig. 226)

Clearly defined circular gray or brown areas with lighter colored centers appear on the eggplant foliage, when numerous causing the leaf to yellow and die. Cankers on the stem at the surface of the soil may

cause seedlings or old plants to fall over. On the fruit a pale sunken rotted area may spread to include the whole fruit. The rotted area becomes covered with small black fruiting bodies.

FIG. 225.—Fusarium wilt on pepper.

Destruction of all diseased plants and crop remnants, rotation to keep at least three or four years between eggplant crops, selection of seed from healthy plants, spraying at weekly intervals for five weeks with bordeaux mixture, starting when the plants are set in the field, preceded by two applications in the seed-bed, and seed treatment with corrosive sublimate 1 to 1,000 for ten minutes, are advisable.

Anthracnose of pepper

Small dark water-soaked depressed areas spread rapidly on the peppers, turning lighter in color as they develop. Later a black layer of fungus spreads over the affected tissue. Then the whole fruit decays.

Methods of control are to destroy diseased fruits, rotate crops, disinfect seed and spray the plants to hold this disease in check. Seed treatment must be done carefully as the seed is delicate. Chupp recommends soaking the seed in water for six to fifteen hours, draining, and soaking in a 1 to 80 solu-

tion of copper sulfate for five minutes, after which it is dusted with lime and planted at once. The spraying schedule involves several applications of 3-6-50 bordeaux at weekly intervals after the plants are set in the field.

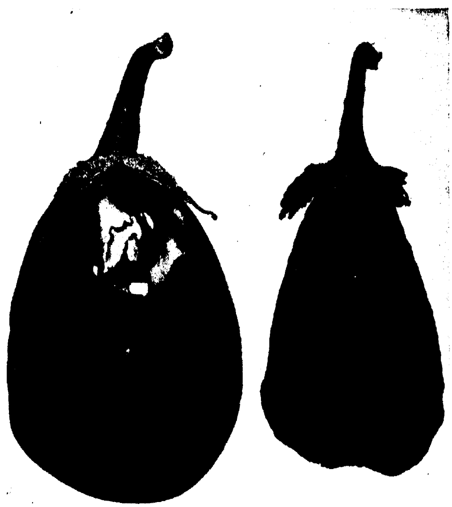


FIG. 226.—Phomopsis blight on eggplant.

Other tomato, eggplant and pepper diseases

Mosaic	Damping-off
Streak	Phoma-rot
Blossom end-rot	Verticillium wilt
Grand Rapids disease	Western yellow blight
Phytophthora foot-rot	Ascochyta blight
Collar-rot	Botrytis stem-rot
Buckeye-rot	Cercospora leaf-spot
Verticillium wilt of eggplant	Bacterial brown-rot

Rhizoctonia fruit and stem-rot....... (See potato, page 468)

CHAPTER XXXIV

PESTS OF THE SWEET POTATO

KEY FOR DIAGNOSING SWEET POTATO PESTS

Foliage yellow

Stem-rot, black-rot, foot-rot, Sclerotium rot.

Foliage spotted

Black-rot, Septoria leaf-spot, Phyllosticta leaf-blight.

Foliage dying

Stem-rot, black-rot.

Foliage eaten

Pedlers.

Root and stems injured or discolored

Black-rot, foot-rot, soil-stain, soil-rot (Fig. 227), Sclerotium rot, soft-rot and dry-rot (in storage), charcoal-rot, surface-rot, Java black-rot, sweet-potato-weevil, nematodes.

IMPORTANT SWEET POTATO PESTS

No regular spraying schedule is used to combat the enemies of the sweet potato, although occasionally the vines are sprayed to control pedlers. Dipping the seedlings before setting them out in the fields to control gold-bugs, scurf, soil-stain, and black-rot is practiced, but seed selection, soil sterilization, and the use of sanitary propagating methods are most relied on.

Tortoise-beetles (pedlers)

These small insects about ¼ inch long, resembling a miniature turtle, feed on the leaves of the newly transplanted vines, and later the larvæ and new brood of beetles further damage the vines.

Spraying with 1 to 1½ pounds of powdered lead arsenate

FIG. 227.—Sweet potato pox or soil-rot.

FIG. 228.—Stem-rot on sweet potato.

to 50 gallons of water, directing the spray as far as possible to hit the under sides of the leaves, will control this insect.

Sweet-potato-weevil

Larvæ of this weevil burrow in potatoes, causing decay. Many generations ensue as long as the food plant remains. Abandonment of the crop for several years in infested areas, the use of new distant fields, the removal and burning of crop remnants, and care not to introduce the weevil into uninfested localities are advised.

Stem-rot (vine-wilt, yellows), foot-rot and black-rot (Figs. 228-230)

Poor stands in the field, with young plants yellowing and wilting due to a cracking along a swelling on the stem, are caused by stem-rot. The disease is carried in the roots, which show a brown ring in the top end.

Foot-rot causes the base of the stem to turn brown just above the surface of the soil, the lower leaves to yellow and drop off, and the vine to wilt and die.

Dwarfed sprouts, with yellow foliage and blackened stems or rootlets, appearing in the seed-bed, and later in the field, indicate black-rot. The portion of the plant above the lesion may die. Sometimes every root in a hill will also be black-rotted, while the stems appear healthy. Roots are paler in color than healthy ones and bitter to taste, the bitterness increasing in storage. The disease spreads in storage.

The use of clean seed, the rogueing out of plants during the season, and the disinfection of hotbeds, and use of manure free from sweet potato refuse are advised for these diseases.

Other sweet potato diseases

Slime mold	Septoria leaf-spot
Soil-rot (pox, pit)	Java black-rot
White-rust	Scurf
Cottony-rot	Soft-rot
Texas root-rot	Ring-rot
Phyllosticta leaf-blight	Dry-rot

Charcoal-rot

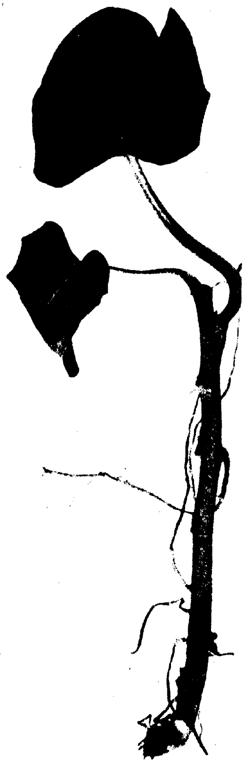


Fig. 229.—Black-rot of sweet potato on plant.

Fig. 230.—Black-rot on sweet potato.

CHAPTER XXXV

PESTS OF COTTON

COTTON, the second most valuable farm crop grown in the United States, is host to a long list of enemies, of which the bollworm and boll-weevil are of outstanding importance. The diseases sometimes reach such proportions that the profitable cultivation is impossible, yet none adapts itself readily to control by spraying. The use of disease-resistant varieties, rotation of crops, disease-free seed of resistant varieties, sanitation, and cultural methods which promote vigorous growth, serve to overcome the disease handicaps. The insects are not as readily disposed of, and defensive measures are essential against some of these pests if cotton is to be grown successfully. Spraying and dusting are the usual means of control.

The dusting of cotton for the boll-weevil is the chief control operation. Most other chewing insects are fairly well controlled by the same means and therefore need be given little special consideration. Spraying operations are resorted to for the control of red-spider, but much can be done to combat this pest by destroying other host plants.

The cotton boll-weevil

The "flaring" of the bracts on the cotton squares and the shedding of large numbers of squares is the most conspicuous indication of the presence of the cotton boll-weevil. A curved white grub with yellowish-brown head within the square is the larva. The larva develops from the egg into a mature weevil in about three weeks, and as summer progresses it in turn attacks more squares and bolls, until the entire crop may be ruined. The weevil may be greatly reduced by poisoning

with calcium arsenate, sanitation, early planting, and good cultural practices to secure vigorous productive plants. Calcium arsenate is applied with dusting machines, varying from the hand-duster to the aeroplane, from 5 to 7 pounds to the acre being used. The following rules, taken from Farmers' Bulletin 1329, have been prepared for the guidance of those planning to poison:

Use only pure calcium arsenate in the form of a dry powder.
Apply this only in dust form.
Purchase this to conform to the following specifications:
- Not less than 40 per cent total arsenic pentoxid.
- Not more than 0.75 per cent water-soluble arsenic pentoxid.
- Density not less than 80 or more than 100 cubic inches per pound.

Use only dusting machinery especially constructed for cotton dusting (Fig. 231)
Poison only when the air is calm and the plants are moist. In most sections this means making only night applications.
Use about five to seven pounds of calcium arsenate per acre for each application.
Start poisoning when the weevils have punctured from 10 to 15 per cent of the squares.
Keep your cotton thoroughly dusted until the weevils are under control. This usually means about three applications at the rate of one every four days.
Then stop poisoning until the weevils again become abundant.
If the weevils become abundant early enough to injure your young bolls, make one or two more applications late in the season.
If you have a heavy rain within 24 hours after dusting, repeat this application immediately.
Do not expect to eradicate the weevils. Poisoning merely controls them sufficiently to permit a full crop of cotton and you can always find weevils in the successfully poisoned field.
Keep your cotton acreage low and do everything possible to increase your yield per acre, as it costs just as much to poison one-quarter bale per acre cotton as one bale per acre cotton.

Always leave an occasional portion of a crop unpoisoned for comparison with the adjoining poisoned tract. This will show how much you have increased your yield by poisoning.

In Florida,[1] marked reduction of weevil injury has accompanied the removal and destruction of all squares in the early spring when they average only about two squares to a plant, followed by immediate and thorough dusting of the terminal

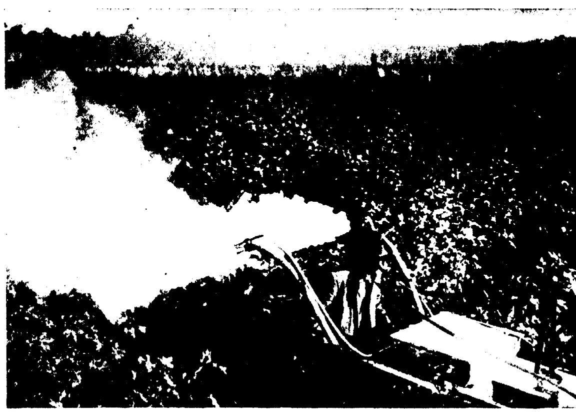


FIG. 231.—Dusting cotton with a two-row duster.

buds where the remaining weevils are forced to feed. This method is of particular interest for use on low-yielding land where a heavy dusting schedule throughout the season would be impractical.

Since 1922 the United States Department of Agriculture has been carrying on experiments to work out the possibility of dusting cotton by aeroplane (Fig. 232). B. R. Coad, in charge of the Tallulah, Louisiana laboratory feels that this method is entirely practical. Over 50,000 acres were dusted in

[1] Smith, G. D., Fla. Exp. Sta. Bull. 165. 1922. *A Preliminary Report upon an Improved Method of Controlling the Boll-Weevil.*

this manner in 1925, the Huff-Daland Company of Ogdensburg, New York, doing most of the work.

The bollworm (corn ear-worm)

Pale green to almost black larvæ bore into squares and bolls and eat out the interior, later leaving by another hole

FIG. 232.—Dusting cotton by aeroplane. Note cloud of drifting dust made on previous trip.

to pass to another boll. A single worm may thus injure all the bolls on several branches before becoming fully developed. It is easily distinguished from the boll-weevil larvæ by the color and size. Another similar pest, the pink bollworm, is prevalent in Mexico, and strict quarantine is being maintained to keep it from becoming established in the United States. Control measures for the boll-weevil will take care of the bollworm.

The cotton leaf-worm

This worm varies in shades and colors from yellowish-green without prominent stripes to darker green with a black and yellow stripe. It is sometimes called the cotton army-worm. It may appear at any time from early to late in the season, sometimes defoliating the plants. If leaf-worms attack early, they may do great damage, and should be combated. Late attacks within a few weeks of harvest may be beneficial by hastening ripening and cutting off the food supply of the boll-weevil.

Control measures aimed at the boll-weevil keep the leaf-worm in check.

The cotton red-spider

These minute red mites suck the juices from the leaves, causing them to turn red. If serious they may kill the plant. They are carried over the winter principally on the pokeweed and violet, and destruction of these plants is the first step in control. When this insect appears in a cotton field, the plants should be sprayed either with concentrated lime-sulfur, 1 to 50, potassium sulfid, 1 ounce to 2 gallons water, 1 per cent kerosene emulsion, or flour paste solution.[1]

The cotton-hopper (cotton-flea)

The shedding of very small squares and changes in growth of plants, which become abnormally tall, with few or no branches, and little or no fruit, is attributed to a virus injected into the plant by the cotton-hopper. It is found principally in Texas and somewhat in the Southeast.

[1] U. S. Dept. Agr. Farmers' Bull. 831, *The Red Spider and How to Control It.*

Flowers of sulfur should be dusted or sprayed on the plants usually about late April, or when the hoppers appear, and thereafter with sufficient frequency to keep down the pest. Destruction of horsemint and goatweed are also recommended.

Grasshoppers

The differential and southwestern lubber grasshoppers attack cotton fields in large numbers occasionally, and require control measures. The use of poisoned baits is probably the most effective method of control. (See page 46.)

Other cotton insects

- Cotton aphis
- Southern grass-worm
- May-beetles
- Cotton-square borer
- Cotton-stainer
- Flower-beetles
- Leaf-beetles
- Salt marsh caterpillar
- Cutworms
- Leaf-cutting ant
- Cotton boll-cutworm
- Cotton bugs
- Cotton wireworms
- Corn root-aphis

CHAPTER XXXVI

PESTS OF TOBACCO

PROFITABLE tobacco culture depends greatly on the production of strong healthy disease-free seedlings in the plant-bed. Arsenical dusts and some arsenical sprays are used widely in controlling the bud-worm and horn-worm, but little spraying with fungicides is done, most of the diseases being held in check by cultural methods centering around the plant-bed. Sterilization of the seed-bed to control diseases and kill hibernating insects and weed seeds, is now recognized as an important factor in tobacco-growing. As an adjunct to this, the spraying of plants in the seed-bed with bordeaux mixture, for wildfire, black-fire, blue-mold, and the like, is practical. Crop rotation, plant-bed and field sanitation, seed disinfection, and proper ventilation of plant-beds, contribute toward holding pests under control.

Inasmuch as no general spraying is done in the field to control fungous pests, a detailed discussion of the various tobacco diseases will not be given. Soil sterilization is discussed in detail on pages 241 to 253. The following summary [1] shows the sanitary measures which should be undertaken, particularly on farms where mosaic and bacterial leaf-spots have been prevalent. If damping-off and root-rot are the only diseases troublesome, the use of new soil, or the sterilization of soil will ordinarily suffice.

(1) Plant beds should preferably be placed a considerable distance from the location of the seed beds or fields of the

[1] Johnson, J., *Tobacco Diseases and Their Control.* U. S. Dept. Agr. Bull. 1256. 1924.

previous year and away from tobacco-curing barns and weedy areas.

(2) No tobacco refuse (trash) or stems should be used as fertilizer on seeds beds. Refuse should preferably be cleaned up and destroyed before seed beds are started.

(3) Plant-bed frames should be made of new material, or the old material should be disinfected by painting or sprinkling with some disinfecting solution such as formaldehyde or corrosive sublimate.

(4) If new seed-bed covers are not used, the old cloth covers should be sterilized by boiling one hour, and sash should be disinfected with the frames.

(5) If new land is not used for seed beds—i.e., wood lands, new breaking, or sod—the soil for the seed beds should be sterilized, preferably by steaming for at least 30 minutes.

(6) In case the tobacco seed to be used is likely to be infested with wild-fire or black-fire it should be disinfected with corrosive sublimate (1 part to 1,000 parts of water). Place the seed in a cheesecloth bag, dip it in the solution, and stir it about for 10 to 15 minutes. Rinse thoroughly with pure water and dry as rapidly as possible. This method of sterilization can be used only with seed sown in the soil without previous sprouting, since sprouting is otherwise interfered with. Silver-nitrate (1 to 1,000) treatment for 15 minutes gives as good disinfection as corrosive sublimate and permits sprouting of the seed before sowing.

(7) Do not sow the seed too thickly (1 ounce to each 800 to 1,000 square feet is usually sufficient). Do not overwater the plants, and ventilate frequently by raising or removing the covers, especially when glass covers are employed.

(8) Inspect the beds at intervals for diseased plants, and if any are noted destroy them at once and soak the infected area with formaldehyde solution (1 to 25). Carefully avoid these infected areas when weeding or pulling plants, since the parasites are readily spread at such times. If infection is general in the seed bed it is safest to procure healthy plants from other sources for transplanting.

Tobacco horn-worm

Large green and sometimes brownish caterpillars, tiny at first, but when full grown becoming 3 or more inches long, marked with oblique stripes on the sides of the segments of

the body, feed ravenously, while young, on tobacco leaves. They resemble the tomato horn-worm.

Dusting plants with powdered lead arsenate, 3½ to 5 pounds to the acre, once in late June and again in early August or whenever the worms appear on the plants is recommended. Lead arsenate has caused less burning than other arsenicals. Calcium arsenate or paris green should not be used. Hand-picking is practiced for small patches. Fall plowing destroys many of the grubs in the soil.

Tobacco bud-worm

Worms varying in color from light green with paler longitudinal stripes to dark reddish-brown or even dark gray, feed on the tobacco bud, making holes and causing misshapen leaves. The worm is about 1½ inches long at maturity. It is controlled [1] by placing in the unfolding buds a small quantity of a mixture of 1 pound of powdered lead arsenate to 75 pounds of bolted or sifted corn-meal (approximate 6 heaping teaspoonfuls to one peck of corn-meal). The poison should be evenly distributed throughout the corn-meal. The first application should be made as soon as the plants are established in the field. For the first two or three applications the dust can be sifted on the plants, but later applications require the opening of the buds with one hand, placing inside a small amount of the dust with the other. For best results the buds must be treated twice a week until the plants have been topped. Seed-beds should be screened and crop remnants destroyed after harvest.

Tobacco flea-beetle

Dark brown flea-beetles eat small irregular holes in the leaves, particularly on the shaded parts of the plants, reducing greatly the market value of the leaves. Damage is par-

[1] U. S. Dept. Agr. Farmers' Bull. 819. 1917. *The Tobacco Budworm and Its Control.*

ticularly bad late in the season. Sterilization of seed-bed, screening the seed-bed tightly with cheesecloth having at least 25 strands to the inch, and dusting the crop with lead arsenate dust are recommended.

Farmers' Bulletin 1425 recommends dusting the plant-bed just before transplanting with a mixture of 1 pound of paris green to 5 pounds of lead arsenate, using 1 pound to 100 square yards of bed, and dusting the crop in the field with the same mixture employing 4 to 6 pounds to the acre, whenever five to ten beetles appear on a plant. This also controls horn-worms and tobacco worms.

CHAPTER XXXVII

SEED TREATMENT

SEED treatment is a simple process for most vegetables. The quantities of seeds used are small, except in the case of the Irish and sweet potatoes, and the materials are easy to obtain and prepare. It must be realized, however, that most of the materials, particularly corrosive sublimate, are toxic, and if not properly used they may injure the seeds. Therefore, directions should be followed closely, particularly those regarding the length of time of immersion.

When small seeds, such as cabbage, are being treated, not over ¼ pound of seed should be tied loosely in a cheesecloth bag and immersed in the disinfectant, thus insuring thorough penetration by the solution. The solution should be discarded after use.

In making up corrosive-sublimate or copper-sulfate solution, wooden, earthen, or glass containers should always be used, as these poisons will corrode metals. The temperature of corrosive-sublimate solution should be between 45° and 70° F.

When large quantities of seeds are treated, as in the case of the potato crops, considerable ingenuity is required in rigging up equipment to facilitate the task. If potatoes are placed in clean disinfected sacks, these can be dipped in the barrels of the solution; this will make the dipping simpler. Dirty sacks should not be dipped. If no clean sacks are available, the potatoes should be dumped loose into the barrels. For this purpose it is well to have the barrels elevated about 30 inches and tapped at the bottom, so that the solution can

be drawn off into other barrels after the immersion period is ended. When potatoes are in crates a rectangular wooden or concrete tank makes a convenient receptacle for dipping.

The methods of keeping up the strength of the disinfecting solution are many and various. Beside the one mentioned in the accompanying table, the Wisconsin Agricultural Experiment Station recommends the following:[1]

"The strength of corrosive-sublimate solution can be maintained by adding ½ ounce (of corrosive sublimate) for every 4 bushels of seed potatoes treated, and keeping the volume of water constant. This is based on the 1½ to 2 hour treatment. If a shorter treatment is given, a correspondingly smaller amount of chemical should be added. For example, if 4 bushels are soaked for 30 minutes, add ⅛ ounce of corrosive sublimate. For convenience have the corrosive sublimate in a stock solution, strength 1 ounce to one quart of water, made up in fruit jars or stone crocks."

Other materials can be used in treating seed potatoes. Formaldehyde has been a standard disinfectant, but is waning in popularity because it is not quite as effective as corrosive sublimate, causes discomfort to the eyes, nose, and throat of the operator, and frequently injures the seed, thus lowering the germination.

Organic mercury, as exemplified in Chlorophol, Corona No. 620, Uspulun, Germesan, Semesan, and others, was used in Germany at least as early as 1912 and perhaps before. Chlorphenol mercury is the basis for these preparations. They have come into considerable promise recently for the control of diseases of the vegetable and grain crops. These compounds are more or less insoluble in pure water, but will dissolve in alkaline solutions. Therefore, the commercial preparation contains alkalis. For dust treatment from 2 to 3 ounces to a bushel are used. In preliminary trials these have given as satisfac-

[1] Brann, J. W., and Vaughan, R. E., Wis. Agr. Exp. Sta. Bull. 331. 1921.

SEED TREATMENT SCHEDULE FOR GRAINS

Crop	*For*	*Material*	*Method*
Wheat	Bunt	Copper-carbonate dust, finely ground	Mix seed thoroughly with 2 oz. of dust per bu. until every grain is coated
Oats	Loose and covered smut	Formaldehyde, 1 pt. to 40 gals. of water	Sprinkle, using 1 gal. per bu. Mix, cover for 6 to 12 hrs., dry, and sow.
Barley	Smuts	Organic-mercury compounds, such as Uspulun, Semesan, Chlorophol, Corona No. 620	Soak for ½ to 1 hr. in a 0.2 to 0.3 solution of liquid organic mercury
Sorghum	Kernel smut	Copper-carbonate dust, finely ground	2 oz. per bu. mixed with seed thoroughly until every seed is covered
Rice	Black smut	Liver of sulfur, 1½ lbs. in 25 gals. water	Soak seed 24 hrs.

SEED TREATMENT SCHEDULE FOR VEGETABLES

Bean	Pod-blight	Corrosive sublimate, 1 oz. to 7½ gals. water	Soak for 10 minutes, rinse, and dry
Beet	Cercospora leaf-spot,	Formaldehyde, 1 pt. to 8 gals. water.	Soak for 10 minutes, rinse, and plant or dry
Celery	Early, late, and bacterial-blight,	Corrosive sublimate, 1 oz. to 7½ gals. water; or hot water, 118° F.	Soak for 10 to 30 minutes. If hot water is used, soak for 30 minutes and rinse in cold water
Corn	Stewart's bacterial-wilt,	Corrosive sublimate, 1 oz. to 7½ gals. water; or dry heating, 140-158° F.	Soak for 15 minutes, rinse, and dry; or heat for 1 hr.
Cabbage and Cauliflower	Black-leg, black-rot	Corrosive sublimate, 1 oz. to 7½ gals. water; or hot water, 122° F.	Soak for 20 to 30 minutes, rinse, and dry. Soak for 30 minutes, dip in cool water, and dry
	Leaf-smut	Hot water as above	
Cucumber and Cantaloupe	Angular leaf-spot, anthracnose, Fusarium wilt,	Corrosive sublimate, 1 oz. to 7½ gals. water	Soak for 5 minutes, rinse, and dry
	Corynespora leaf-spot,	Formaldehyde solution, 1 pt. 40% to 50 gals. water	Soak for 4 hrs.
Eggplant	Phomopsis blight.	Corrosive sublimate, 1 oz. to 7½ gals. water	Soak for 10 minutes, rinse in running water for 15 minutes, and dry

SEED TREATMENT SCHEDULE FOR VEGETABLES—(*Continued*)

Crop	*For*	*Material*	*Method*
Muskmelon	(See Cucumber)		
Onion (sets)	Black-mold	Formaldehyde, 1 pt. to 30 gals. water	Soak for 6 hrs.
Pepper	Anthracnose, bacterial-spot, Cercospora spot, black-spot	Copper sulfate, 1 part to 80 parts water	Soak seed for 6 to 15 hrs. in water, drain, and soak in copper-sulfate solution for 5 minutes, after which the seed is dusted with air-slaked lime and planted at once
Potato	Rhizoctonia, scab, black-leg, powdery-scab, bacterial brown-rot	Corrosive sublimate, 4 oz. to 30 gals. water	Dissolve poison in hot water and add cold to 30 gals. Soak seed for 1½ hrs., and then dry it thoroughly. Discard solution after soaking 3 batches of potatoes, or add enough corrosive sublimate and water to bring the solution back to original strength. Some growers add 1 oz. corrosive sublimate to every barrel of potatoes treated
Rhubarb (roots)	Phytophthora foot-root	Corrosive sublimate, 1 oz. to 7½ gals. water; or formaldehyde, 1 pt. to 30 gals. water	Soak for ½ hr. and rinse Soak for ½ hr. and rinse
Squash	(See Cucumber)		
Sweet Potato	Black-rot, stem-rot, foot-rot, soil-stain, scurf, dry-rot	Corrosive sublimate, 6 oz. to 50 gals. water	Soak seed potatoes 8 to 10 minutes just before bedding. After each 10 bus. have been treated, ½ oz. of poison is added to every 32 gals. of used solution, and it should be brought back to the original volume. After 50 bu. are treated, discard the old solution and make a new batch
Tomato	Bacterial spot, Grand Rapids disease, streak, Fusarium wilt	Corrosive sublimate, 1 to 3000 (1 tablet in 3 pts.)	Soak for 5 minutes, rinse in clean water, and dry. Use solution only once
Watermelon	(See Cucumber)		

FIG. 233.—Oat smut.

tory results as the standard corrosive-sublimate treatment.

Copper carbonate is another new material especially valuable as a means of controlling bunt or stinking smut of wheat and kernel smut on sorghum. It is applied as a dust, and is quick, effective, and inexpensive. It has not proved effective for smut on oats and barley, however.

DISINFECTION OF SMALL GRAIN SEED

Wheat, oats, and barley are attacked by several serious seed-borne diseases, the bunt of wheat, the smuts of oats, barley, and wheat being the most serious. All of these can be controlled readily by proper seed treatment. Formaldehyde or hot water has been the standard disinfectant for many years, but while they give excellent control of the diseases, neither of them is convenient to handle. The formaldehyde interferes with the germination, sometimes causing serious reductions of the stand of grains, especially when weak

or poorly matured seed has been used. New disinfectants are gradually replacing these materials.

Treatment of bunt or stinking smut of wheat

Copper-carbonate dust, 95 to 98 per cent pure and containing 50 to 55 per cent metallic copper, when ground finely enough to pass through a 200-mesh sieve, is the best fungicide for controlling bunt or stinking smut of wheat. Two ounces, or approximately 2 heaping tablespoonfuls of this light green dust, should be mixed thoroughly with each bushel of wheat seed to give control. This can be done easily in a concrete mixer, a churn, or home-made rotating barrel.

It not only controls the bunt, but also stimulates germination. This material, if inhaled, is irritating to the operator, and a dust mask or wet handkerchief should be worn over the mouth and nostrils when treating seed.

Organic-mercury dust and liquid fungicides, such as Chlorophol, Uspulun, Semesan, Germesan, and Corona No. 620 also will control bunt, but they are far more expensive, and the liquid treatments are not as convenient to use as copper-carbonate dust.

Treatment of barley seed

Tisdale, Taylor, Leukel, and Griffiths,[1] of the United States Bureau of Plant Industry, show in experiments carried on by them from 1922 to 1925 that several organic-mercury compounds, including Chlorophol, Corona No. 620, Germesan, Semesan, and Uspulun, have given excellent results in controlling barley smuts. These materials were superior to formaldehyde treatments from the standpoint of germination of seed, control of smuts, and yields. Organic-mercury disinfectants are more expensive than formaldehyde, but—according to these authors—the additional expense is more than compensated for

[1] Tisdale, W. H., Taylor, J. W., Leukel, R. W., and Griffiths, M. A., *Phytopathology,* Vol. XV, No. 11, Nov., 1925.

by increased germination and yields. The material is used in liquid form, dusts not having proved entirely effective.

They found that soaking the barley seed for one hour in a 0.3 per cent solution of Semesan or Chlorophol, or for fifteen minutes in a 0.2 per cent solution of Corona No. 620, gave them the most satisfactory control of smuts and highest yields. Corona No. 620 as weak as an 0.05 per cent solution was satisfactory when the seed was soaked for an hour.

Organic mercury is very poisonous, and caution should be observed not to place treated grain where animals can reach it.

Treatment of oat seed

Oat smut may still be controlled best by the formaldehyde treatment, according to the United States Office of Cereal Investigations.[1] Dust treatments of all kinds have been ineffective in controlling oat smut (Fig. 233). Therefore, liquid treatments have been more widely employed. One pint of 40 per cent formaldehyde is put in 40 gallons of water and the seed is spread out on the barn floor and sprinkled, using about a gallon to a bushel. The grain is shoveled over a few times to mix the formaldehyde thoroughly with the grain, covered with canvas or sacks, and allowed to stand for six to twelve hours, dried, and then sown. If stored, all bags used for the seed should be disinfected first. Machinery used in sowing should also be disinfected with lime or formaldehyde.

[1] Tisdale, W. H., Taylor, J. W., Leukel, R. W., and Griffith, M. A., *Phytopathology,* Vol. XV, No. 11, Nov., 1925.

CHAPTER XXXVIII

THE CONTROL OF PESTS OF THE DOORYARD GARDEN

THE commercial gardener and fruit-grower has a fairly simple task in fighting pests compared with the man who is ambitious to keep his ornamentals and his garden rid of their enemies. The grower with extensive acreages usually has a limited number of crops, each of which is grown on a large scale, with the requisite machinery for caring for them. His mind is concentrated on the problem, and he has learned the important requirements for these crops and has little trouble keeping up with the advent of various pests. But the backyard gardener is usually occupied with other things, and he gardens only as an avocation. He grows a wide variety of products, and would need to be a human encyclopedia to retain in his mind a knowledge of even the principal pests of each of his crops and to watch out for each in its time. Neither can he conveniently keep the machinery or even materials on hand with which to combat all garden troubles.

He does have one or two advantages, however. The ground which he works is generally freer from pests than lands which have grown crops in a large way for many years. His units are small, so that he can perform many operations which would be impossible on a large scale. Finally, he is growing produce for his own use instead of for a highly competitive market, so that many imperfections which would count heavily against the produce in trade are overlooked. In fact, many gardeners would enjoy a wormy home-grown apple or an undersized tomato to perfect specimens in the regular channels of trade. Perhaps the crispness and flavor of produce freshly picked

more than overcome the disadvantages of certain blemishes made by insects and diseases.

There are three classes of pests operating in almost every garden, against which the grower must protect himself: the caterpillars, or tissue-eating pests; the plant-lice and plant-bugs, or sucking-insect pests; and the rot and spot fungi. It is largely immaterial exactly which species of insect or disease is making the injury. It is rather the nature of the injury that counts. In Chapter II principles underlying the control of insects and diseases are discussed. By keeping in mind the points presented there, it is not difficult to be prepared to ward off most of the pests with which the dooryard gardener may have to deal. There it was found that for foliage- or stem-eating insects, such as the caterpillars, the arsenical poisons are effective. Against the scale, aphis, plant-bugs, and other sucking insects, contact sprays must be used, and the lime-sulfurs, soluble sulfur, and nicotine sulfate and soap or nicotine dust are the most satisfactory. To combat rot and spot fungi, a fungicide is necessary, and bordeaux mixture, copper-lime or colloidal copper-dust, or, for more tender plants, a wettable sulfur or a sulfur dust, are the most practical.

The method of application of these spray materals is probably a matter of more concern to the average gardener. He knows that in about all of the standard spray materials there is a fair proportion of active ingredients. But regardless of what he uses, there is the laborious and somewhat unpleasant task of applying the remedy. Two methods are available, dusting and spraying.

Dusting fruit and vegetable crops in the dooryard has several outstanding advantages over spraying. The material will not stain the paint on buildings; it can be applied quickly and comparatively easily by one man; and it is not as messy and unpleasant to handle as liquid materials. The disadvantages of dusting are that it is not possible to apply the materials when the wind is blowing; it does not give as good control of

some diseases as liquid spraying; and it is less satisfactory in the control of aphis on tree-fruits. Dusts are now available for use against scale during the dormant season and will keep these pests sufficiently in subjection for the purposes of the backyard gardener. When all points are weighed, then, the dusting method seems to be the most practical means for the home-gardener to protect his plants from pests.

DUSTING IN THE GARDEN

Four dust materials are essential for control of garden insects and diseases: a dormant dust, such as the soluble-sulfur for peach leaf-curl and to a certain extent for scale; a sulfur-lead arsenate dust for fungous diseases and biting insects; a nicotine dust for aphis and plant-bugs; and, lastly, a copper dust for controlling grape, berry, potato, and vegetable diseases. All of these materials can be secured readily from horticultural supply houses and should be ordered during the winter to be on hand at the beginning of the season.

The dust most largely employed where there are any tree-fruits is the sulfur lead-arsenate lime combination. Proportions of the ingredients are expressed numerically and in that order. Thus a 75-5-20 dust means 75 per cent sulfur, 5 per cent lead arsenate, and 20 per cent hydrated lime. The 75-5-20 and the 80-10-10 dusts are excellent for tree-fruits, the 75-5-20 being less likely to cause any burning on tender foliage like that of the peach. A mature peach tree will require ½ pound to an application, and three or four applications should be made. Mature apple trees will each require 1½ to 2 pounds to an application, and four to seven applications are desirable. Young or small trees will require proportionately less material.

Nicotine dust is probably the next most important material for the backyard gardener. The dust is made of either nicotine sulfate or free nicotine and some form of lime, and the analysis on the package should tell the percentage of nicotine

or nicotine sulfate present. While low concentrations of nicotine will kill many aphis and plant-lice, the higher concentrations are far more effective and reliable, and the use of at least a 3 per cent actual nicotine or 7 per cent nicotine-sulfate dust is strongly advised. (See discussion on page 216.) This material can be secured in tight metal drums in any quantity, and the container should be open only when actually measuring out material from it. A little grease around the edges of the lid will help to seal the can tightly.

Copper-lime or colloidal copper dust must be used to prevent grape, berry, and some vegetable diseases. Lead arsenate or calcium arsenate is added to make it effective for killing foliage-eating insects. The same supply houses that handle the other dusts will usually have this material. It should never be used on peach or other tender foliage, and only on apple foliage when bitter-rot, apple-blotch, or anthracnose must be combated.

Soluble-sulfur dust is used for dormant spray applications to fruit-trees infested with San José scale and to peach trees for scale and peach leaf-curl. It has the most limited use of any of the four dust materials needed by the dooryard gardener.

The dust is applied by means of small blowers or puffers (Figs. 234, 235). The blower type has a fan run by a hand crank. The puffer dusters are operated by a bellows. For dusting vegetables or very low trees or bushes, the bellows or puffer type of duster is highly efficient. For dusting large trees, however, the blower type is preferred because sustained drafts of dust can be blown through the trees. A round discharge pipe, extended to a length of five or six feet, should be used when dusting fruit-trees. (See page 229.)

Dusting trees with these machines should be done when the air is calm, and, except with nicotine dust, best results are secured if the trees are damp with dew. Therefore, the optimum time for dusting is early in the morning or late in

the evening, and this coincides with the leisure of most home-gardeners. Ten to twelve old apple trees can be covered in an hour if conditions are right.

Low trees—those up to ten or fifteen feet in height—are dusted from the ground. When higher trees are encountered, the operator should place a ladder up in the tree so that he can get far enough into the top to be able to handle the crank

FIG. 234.—The dust-gun is an important weapon for the dooryard and amateur gardener.

and discharge pipe easily, and the dust should be blown down over the upper parts. If there is a pronounced drift to the air, the ladder should be placed up against the windward side of the tree and the dust blown so that it will drift through the entire top of the tree. After dusting the tops, one should walk around the tree, dusting the lower branches from the ground.

For dusting ground crops, such as potatoes, peas, tomatoes, and other vegetables, either a hover or a fan-shaped tip may be placed on the end of the discharge pipe. The hover is a conical metal hood into the peak of which a flexible discharge pipe empties. The hover or hood is dropped over the potato plant or small melon vine and a puff of dust given, and the

hood raised immediately and placed over the next plant. In the short space of time occupied in stepping from plant to plant, the hover holds the dust around the vine and gives it a uniform coating. A new type of hover especially adapted for

FIG. 235.—Hand-duster of the fan type; note the tip on the discharge pipe.

the application of dust to the under sides of the leaves has been perfected by C. H. Nissley of the New Jersey Agricultural Experiment Station. (See Fig. 51.) In this hover the dust is delivered through four small horizontal fan-shaped tips placed around the lower edge of the hover. For extensive plants like large melon vines or rows of peas, the fan-shaped

tip is used and the operator cranks or puffs the machine as he walks down the row and directs the material on the plants.

This operation sounds simple, but it is really a tiresome task. Both the crank and the puffer handle are hard to work. However, it is far easier than using liquid materials with a hand-pump and is cleaner, faster, and requires only one man for the operation. Another simple method of applying dust is by means of the cloth bag (Fig. 236). The materials are put in a flour or burlap sack, and the bag is shaken over each plant. This is one of the oldest methods of applying dusts. It is not effective for nicotine dusts for aphis, as these insects are generally on the under sides of the leaves, and a machine which will force the dust up on to the lice must be used.

FIG. 236.—Applying dust materials by means of a flour sack.

LIQUID SPRAYS IN THE GARDEN

If liquid sprays are employed, five materials are essential in the supply cabinet of every gardener. They are lead arsenate, nicotine sulfate, potash fish-oil soap, bordeaux mixture, concentrated lime-sulfur, and wettable sulfur. The arsenate of lead is most conveniently handled in the powdered form. It does not deteriorate to any extent in storage, and a 25- or 50-pound package may be purchased from a supply house at a considerable saving over the pound price at the druggist's.

Nicotine sulfate is on the market in two or three forms, most of them having a 40 per cent nicotine content. It is put up in cans ranging from ½ to 10 pounds. It is least expensive when purchased in the 2½- or 10-pound sizes, and there is doubtless less wastage involved when a larger can is used. Potash-fish-oil soap can be secured through any sprayer supply house, and is valuable both when used alone and in combination with the nicotine sulfate.

Concentrated lime-sulfur is an essential spray to rid trees of scale in the dormant season, and to a certain extent for summer use on apples, plums, and cherries. It comes in both liquid and dry form, and the latter is most convenient for the dooryard gardener to handle. It can be bought in metal drums of various sizes and can be stored indefinitely. It is true that the dry form is not quite as effective as the liquid because of the lower quantities of effective sulfur present in it when used at the strength customarily recommended by the manufacturer. However, it is an entirely satisfactory dormant spray material when used a little stronger than recommended on the package, and this increase in concentration can be made safely because there is no danger of burning or otherwise injuring the trees in the dormant condition. The spraying recommendations made by the agricultural colleges and experiment stations are based on liquid concentrated lime-sulfur testing 32° Baumé. To get a proportionate amount of sulfur from standard dry lime-sulfur analyzing 85 per cent active ingredients, the gardener must use 4 pounds for every gallon of liquid concentrated lime-sulfur recommended.

The bordeaux-mixture supply brings up a more difficult problem. Fresh home-made bordeaux mixtures are most effective, but they are more or less out of the question because no backyard gardener cares to go to the trouble of making up these materials, even though the home-made materials are far less expensive than the ready-prepared proprietary compounds. These latter are of variable compositions and the

same results cannot be expected of them as of the fresh home-made products (see page 89). According to the recommendations of some agricultural experiment stations, the dry "two-powder" bordeaux mixtures are preferred to the paste forms.

Combinations of bordeaux mixture and lead arsenate are on the market in the form of "bordeaux leads." These are usually pastes and are merely diluted with water. Here the variability of the strength of both the bordeaux mixture and lead arsenate is open to question. The gardener will need a supply of lead arsenate on hand anyway, so he may be safely advised to buy bordeaux mixture alone and then add his own lead arsenate.

Applying the material is the worst feature connected with the use of liquid sprays. The gardener can usually afford only the simplest of pumps, and these lack the efficiency of the heavier outfits. Three types of sprayers are adapted to his use: the atomizer, the bucket-pump, and the barrel-sprayer mounted on wheels (Fig. 237). These outfits are described on pages 114 to 122.

Thoroughness in spraying is essential to success, and the use of hand machinery increases the necessity for careful work. Sufficient applications to protect the plants must be made. Many plants require five or six sprayings each season, and even though three or four may be applied, if the organism attacking the plant is still present, it may ruin the crop in spite of the three or four sprays earlier in the season. More frequent sprays are required in wet seasons than in dry.

There are several control methods for garden insects, particularly those that do not require spraying with insecticides. Hand-picking of caterpillars, cutworms, potato-beetles, and other large more or less inactive insects is one method. On house plants scale insects may be removed by hand or by hand washing. Tent-caterpillars, fall webworm, and red-humped and yellow-necked caterpillars on fruit-trees may be either hand-picked or burned with a kerosene torch. Dipping may be practiced, especially in controlling plant-lice on orna-

mentals, the slender flexible tips of which may be bent over into a pan of nicotine spray. In fact, when the leaves have been curled, a more efficient job can be done in this way than by spraying with high pressure. Insects may be jarred into shallow pans of water on the surface of which is a thin film of kerosene. Cutworms and squash-bugs may be trapped by lay-

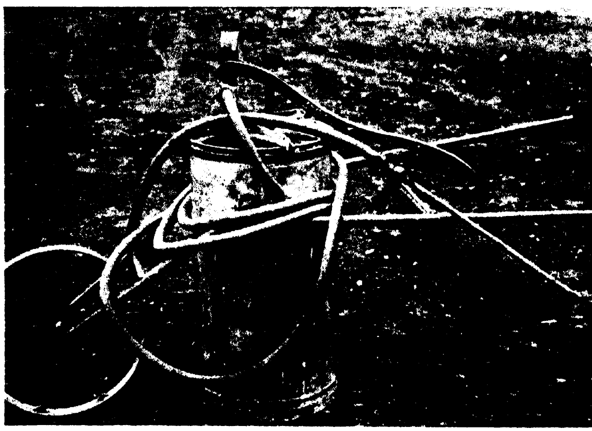


Fig. 237.—Hand-sprayer mounted on a wheel.

ing boards between the rows. The insects will hide under them and the boards may be turned over and the insects easily trampled. Poisoned baits placed under these boards or in the rows will kill many worms. The burning of crop remnants and thorough working of the soil will assist in the control of some pests.

Spraying schedules are tables prepared to tell the grower when to spray, what materials to use, and what pests he is combating by his applications. They are based both on the calendar and on the season. The latter kind makes recommenda-

tions in terms of the stage of development which the plant has reached and is generally more accurate. These schedules are especially valuable for protecting crops against attacks of fungi, because fungous troubles must be prevented rather than controlled once they have appeared. Schedules are probably of more value in controlling pests of fruit crops than of vegetables, because losses to fruit are more regular and the pests appear with greater uniformity than on vegetable crops. The best spray schedules are those prepared by the agricultural college and experiment station in one's own state. These are usually designed rather from the standpoint of the commercial grower than the dooryard gardeners, and there are generally more applications recommended than the latter would apply. However, a knowledge of the most important pests can be gained from these schedules and the applications best designed to control them.

Some general rules may be laid down for the amateur gardener in considering the pests to be looked for and the number of applications to be made:

1. When the foliage is being eaten, apply lead arsenate as either a spray or dust.

2. When small, delicate, soft-bodied plant-lice are present, usually on the under sides of the leaves, use a 3 per cent nicotine dust or a spray made of nicotine sulfate and soap. The presence of aphis is usually indicated by curled leaves on the tips of shoots.

3. Whenever the spray schedule says to put on a fungicide to protect plants from some disease, put it on, even though no evidence of disease is seen at that time. Copper or sulfur mixtures are to be used.

4. Whenever lead arsenate is needed to control a leaf- or fruit-eating pest, use the fungicide with it, or vice versa. It will result in cleaner fruit. That is one reason for buying the copper and arsenic or sulfur and arsenic dusts already combined.

5. Never spray when the temperature is above 90° F., and chose clear, cool, dry days, preferably.

PRINCIPAL INSECT AND FUNGUS PESTS

Aphis and caterpillars, especially climbing cutworms, are the bane of the amateur gardener's existence. The aphis appear at any and all times during the summer on rose bushes, vegetable and fruit crops, house plants, and other shrubs. They vary in color from colorless to black, there being yellow, green, pink, brown, and black species. The color, however, does not affect the damage or means of control. They suck the juices from the succulent tips, causing the leaves to curl, and the plants to grow yellow and stunted and occasionally to die. When aphis get a head start on the grower, they are protected by the curled leaves and are very difficult to dislodge. Nicotine sprays or dusts are very effective. The efficiency of sprays is much increased when soap is added. Small quantities of liquid nicotine spray solution may be made by placing a teaspoonful of 40 per cent nicotine sulfate to 1 gallon of water rendered soapy with a piece of common laundry soap one inch square. Nicotine dusts need no preparation.

Caterpillars, cutworms, fruit-worms, and many forms of beetles feed upon foliage and fruit. Their damage is easy to identify because the foliage shows the marks of their presence. If mechanical methods of control, such as hand-picking, are not practicable where such tissue-eating insects appear, lead arsenate sprayed or dusted over the parts attacked will usually be effective. Small quantities of spray may be made up by using 3 teaspoonfuls to 1 gallon, or 1½ ounces to 5 gallons of water. Lead arsenate is a powerful poison, and may sometimes burn foliage slightly. To avoid this it is well to use an equal amount of hydrated lime with the arsenate in the spray solution. Poisoned baits (see page 46) are attractive to cutworms, army-worms, and grasshoppers. These baits

must be used with caution in the dooryard garden, as they may be eaten by chickens, dogs, or other domestic animals. Many of the foliage-eating insects appear regularly at a certain time in the year and protective sprays may be applied in advance. The codlin-moth which attacks the apple, and the grape berry moth are two examples of these. The spray schedules for different plants should be studied and followed as closely as possible in order to kill such pests before they do their damage.

Various rots and spots appear at different seasons. Generally these must be prevented rather than controlled, and protective coatings must, therefore, be applied before the spots appear. Again the spray schedules are useful, as they predict the kind of diseases and approximate date of appearance. Sulfur and copper sprays are the usual materials employed. On fruit-trees and on ornamentals, sulfur sprays are usually safest. Concentrated lime-sulfur, diluted at the rate of ¼ teacup to 1 gallon of water, will do for plants with resistant foliage such as the apple, pear, and European plum, while for more tender foliage such as the peach and Japanese plum, dry-mix sulfur-lime spray, made by using 3 ounces of powdered sulfur, 3 ounces of lime, and 1 teaspoonful of powdered skim-milk to a gallon of water, will be safest. These ingredients should be mixed dry and the water added slowly. Lead arsenate may be added to either of these materials. On vegetable crops and on grapes bordeaux mixture is generally preferred. As the composition of the commercial bordeaux mixtures which the gardener purchases may vary, the directions for dilution on the package should be followed. Before buying or mixing bordeaux sprays, the discussion on page 88 should be read. Copper-lime and colloidal copper dusts and dry powdered bordeaux mixtures are also on the market, and can be applied to the crops with the dusting machine. These are effective for some crops, but not generally as good as liquid bordeaux.

San José, oyster-shell, scurfy, and other scales will appear

at times on shrubs, trees, and house plants. They may be recognized as being small, flat, roundish specks, varying in size from a pin-head to ⅛ inch in diameter. The Lecanium scale, black scale, and many others common to citrus districts are often larger and quite raised. The amateur gardener will see them in fixed positions, as only the young scale move about. If the scale are on shrubs or trees out-of-doors, spraying during the dormant season with a commercial oil spray diluted according to directions on the package, or with 1 pint of commercial concentrated lime-sulfur in a gallon of water, will suffice. In citrus districts the oil sprays are more commonly used where fumigation is impractical, as in the dooryard garden. (See pages 387 to 390 for control of citrus scale.)

When soft-bodied scale appear on tender house plants one of the simplest remedies is to dissolve a half a bar of common laundry soap in a gallon of water and either wash the plants or apply the material with an atomizer. If scale with hard coats or "shields" are present, lemon-oil, a proprietary oil emulsion diluted with warm water, has been found a satisfactory scalecide, according to McDaniel, of the Michigan Agricultural Experiment Station.[1] Foliage may be dipped in this material or the plants sprayed with the solution. McDaniel further recommends that when used on plants with delicate foliage, the lemon-oil solution be washed off with water three or four hours after application, or the next day.

This entire discussion of methods of controlling pests in the dooryard garden is necessarily brief, as many of the points have already been covered in preceding pages. Fuller accounts of insects and diseases attacking specific crops may be found under appropriate headings in other parts of the book. Spray materials and methods are also discussed in detail in other chapters. The amateur gardener is advised to give considerable attention to the more detailed discussions when confronted by problems of a serious nature.

[1] McDaniel, E. I., Mich. Agr. Exp. Sta. Spec. Bull. 134. 1924.

TABLE OF MEASURES FOR THE DOORYARD GARDENER [1]

Equivalents of Capacity

3 teaspoonfuls ½ fluid ounce 4 fluid drams 15 cubic centimeters	1 tablespoonful
16 tablespoonfuls 2 gills ½ liquid pint 8 fluid ounces 237 cubic centimeters	1 cup
1 liquid pint 16 fluid ounces 473 cubic centimeters	2 cups

2 pints = 1 quart
4 quarts = 1 gallon

Note: The pint and quart dry measures are about 16 per cent larger than the pint and quart liquid measures.

[1] U. S. Dept. of Commerce, Bureau of Standards. Miscellaneous Publication No. 39. 1920.

SPRAY DILUTION TABLE

Material	Total amounts of diluted spray in tank, barrel or bucket								
	200 gals.	150 gals.	100 gals.	50 gals.	25 gals.	10 gals.	5 gals.	1 gal.	1 qt.
I. *Winter Strength* Conc. lime-sulfur. 33° Baumé at rate of 1 part to 8 of water	22 gals.	16½ gals.	11 gals.	5½ gals.	2¼ gals.	4½ qts.	2¼ qts.	1 pt.	½ teacup
Same—1 to 9	20 gals.	15 gals.	10 gals.	5 gals.	2½ gals.	5 qts	2½ qts.	1 pt.	½ teacup
Same—1 to 10	18 gals.	13½ gals.	9 gals.	4½ gals.	2¼ gals.	1 gal.	2 qts.	1½ teacup	½ teacup
Same—1 to 15	12½ gals.	9¼ gals.	6¼ gals.	3⅛ gals.	1¼ gals.	2½ qts.	1¼ qts.	1 teacup	¼ teacup
Same—1 to 20	9½ gals.	7 gals.	4¾ gals.	2½ gals.	5 qts.	2 qts.	1 qt.	¾ teacup	3 tab'sp'n
Same—1 to 30	6½ gals.	4¾ gals.	3¼ gals.	6½ qts.	3¼ qts.	2½ pts.	2½ teacups	½ teacup	2 tab'sp'n
Same—1 to 40	5 gals.	3¾ gals.	2½ gals.	5 qts.	2½ qts.	1 qt.	1 pt.	¼ teacup	1½ tab'sp'n
Same—1 to 50	4 gals.	3 gals.	2 gals.	1 gal.	2 qts.	3¼ teacups	1½ teacups	5 tab'sp'n	4 teasp'n
II. To make a 1% oil spray from a 66⅔% stock emulsion made by emulsifying oil and water in the proportion of 2 gals. of oil in 1 gal. of water	3 gals.	2¼ gals.	1½ gals.	3 qts.	3 pts.	2½ teacups	1¼ teacups	¼ teacup	1 tab'sp'n
To make a 2% oil spray from same stock emulsion	6 gals.	4½ gals.	3 gals.	1½ gals.	3 qts.	2½ pts.	2½ teacups	½ teacup	2 tab'sp'n
To make a 3% oil spray from same stock emulsion	9 gals.	6¾ gals.	4½ gals.	2¼ gals.	4½ qts.	3¾ pts.	3¾ teacups	¾ teacup	3 tab'sp'n
III. Powdered acid lead arsenate 1 lb. to 50 gals. of spray	4 lbs.	3 lbs.	2 lbs.	1 lb.	8 oz.	3¼ oz.	1½ oz.	3 teasp'nf'l	1 teasp'nf'l

Powdered acid lead arsenate, 1½ lbs. to 50 gals. of spray...	6 lbs.	4½ lbs.	3 lbs.	1½ lbs.	12 oz.	5 oz.	2½ oz.	4½ teasp'nf'l	1 teasp'nf'l
Paste acid lead arsenate, 2 lbs. to 50 gals. of spray......	8 lbs.	6 lbs.	4 lbs.	2 lbs.	1 lb.	6½ oz.	3 oz.	6 teasp'nf'l	2 teasp'nf'l
Paste acid lead arsenate, 3 lbs. to 50 gals. of spray......	12 lbs	9 lbs.	6 lbs.	3 lbs.	1½ lbs.	10 oz.	5 oz.	1 oz.	2¼ teasp'nf'l
Calcium arsenate powder, ¾ lb. to 50 gals. of spray...	3 lbs.	2½ lbs.	1½ lbs.	12 oz.	6 oz.	2¼ oz.	1¼ oz.	2 teasp'nf'l	½ teasp'nf'l
Calcium arsenate powder, 1 lb. to 50 gals. of spray......	4 lbs.	3 lbs.	2 lbs.	1 lb.	8 oz.	3¼ oz.	1½ oz.	3 teasp'nf'l	1 teasp'nf'l
Paris green, 6 oz. to 50 gals. of spray......	1½ lbs.	1¼ lbs.	12 oz.	6 oz.	3 oz.	1¼ oz.	6 teasp'nf'l	1¼ teasp'nf'l	....
Paris green, ½ lb. to 50 gals. of spray...	2 lbs.	1½ lbs.	1 lb.	8 oz.	4 oz.	1½ oz.	8 teasp'nf'l	1½ teasp'nf'l	....
IV. 40% nicotine sulfate, ½ pt. to 50 gals. (1 to 800).........	1 qt.	1½ pt.	1 pt.	½ pt. (8 fluid oz.)	4 fluid oz.	1½ fluid oz.	¾ fluid oz.	1 teasp'nf'l	....
40% nicotine sulfate, ¾ pt. to 50 gals. (1 to 600).........	3 pts.	2¼ pts.	1½ pts.	¾ pt.	6 fluid oz.	2½ fluid oz.	1¼ fluid oz.	1½ teasp'nf'l	½ teasp'nf'l
V. Bordeaux mixture 4-4-50 (Amounts of copper sulfate and lime).............	16 lbs.	12 lbs.	8 lbs.	4 lbs.	2 lbs.	13 oz.	6½ oz.	1¼ oz.	....
Same—5-5-50........	20 lbs.	15 lbs.	10 lbs.	5 lbs.	2½ lbs.	1 lb.	8 oz.	4 1½ oz.	....

SPRAY DILUTION TABLE (Continued)

Material	Total amounts of diluted spray in tank, barrel or bucket								
	200 gals.	150 gals.	100 gals.	50 gals.	25 gals.	10 gals.	5 gals.	1 gal.	1 qt.
VI. Self-boiled lime-sulfur 8-8-50 (Amounts of sulfur and burned lime	32 lbs.	24 lbs.	16 lbs.	8 lbs.	4 lbs.	1¾ lbs.	13 oz.	3 oz.	¾ oz.
VII. Dry mix sulfur-lime: 8 lbs. sulfur, 4 lbs. lime [1] } 50 gals.	32 lbs. 16 lbs.	24 lbs. 12 lbs.	16 lbs. 8 lbs.	8 lbs. 4 lbs.	4 lbs. 2 lbs.	1¾ lbs. 13 oz.	12 oz. 6 oz.	3 oz. 1½ oz.	....
½ lb. calcium caseinate	2 lbs.	1½ lbs.	1 lbs.	½ lbs.	¼ lbs.	2 oz.	1 oz.	1 teasp'nf'l	....

[1] When lead arsenate is to be used with this spray, the amount of lime should be doubled.

INDEX[1]

[1] Reference numbers in boldface type indicate most important reference.

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